DETROIT DIESEL

Series 53 Service Manual

DETROIT DIESEL®
CORPORATION

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The Series 53 Service Manual has been completely updated. Sections revised since the last manual release (No. 71 dated February, 1985) are as follows:

SECTION	PAGES	REMARKS
General	4	Parts replacement info. added.
General	11	Option label info. added (S.I. 28-D-85)
General	13-14	Cautions added.
General	14-15	Gasket fabrication, removal, etc info. added (S.I. 17-D-85).
General	15	Fluoroelastomer (Viton) caution added (S.I.1-D-89)
1.1	1	Cylinder blocks standardized (S.I. 26-D-85 Rev.)
1.1	3	Engine lifting notice added.
1.1	5	Cautions added.
1.2	1	Caution added.
1.2	1	Fuse plug info. added (S.I. 19-D-86).
1.2	1	One-piece or two-piece construction cylinder liner compression gaskets used (S.I. 5-D-86).
1.2	4	Notice added: DDC does not recommend welding Series 53 cylinder heads.
1.2	6	Info. added: Never install used gaskets or seals.
1.2	6	Fuel connector torque values added (S.I. 16-D-88)
1.2	8	Fuel pipe reuse notice added.
1.2	8-9	Fuel pipe installation torque chart added (S.I. 29-D-87)
1.2	8	Endurion-coated nuts on fuel pipes (S.I. 2-D-86).
1.2	9	O-ring sealed fuel pipe installation info. (S.I. 16-D-88).

1.2.1	2	Notices, Caution added on barring engine.
1.2.1	2	Info. added: Requalify pallets with master rocker arm radius gage J 28599.
1.2.1	5	Cam follower roller pin test procedure added (S.I. 4-D-86).
1.2.1	8	Endurion-coated nuts on fuel pipes (S.I. 2-D-86)
1.2.1	8	Notice added: Do not reuse flared end fuel pipes.
1.2.2	2	Notice, Caution on barring engine added.
1.2.2	3	Low lift/high lift valve spring color identification added; Notice added (S.I. 33-D-86).
1.2.2	5	Revised valve seat insert removal method using tool J 23479-E.
1.2.4	1	Option label info. added; die cast rocker cover info. added.
1.3	2	Flywheel removal caution added.
1.3.4	5	Bearing shell replacement info. added.
1.3.6	1	Vibration damper safety shield info. added (S.I. 9-D-87).
1.3.6	2	Notices. caution on barring engine added.
1.5	2	Notice added: Do not lubricate Teflon-lip seal, wear sleeve.
1.5	5	Caution on barring engine added.
1.6	5,10	Lubrication recommendation added: Use clean engine oil/STP mix when assembling cylinder kit.
1.6	9	Crosshead piston dome inspection info. (S.I. 35-D-85).
1.6	7	High durability piston domes standard (S.I. 10-D-88).
1.6	7	Notice added: Do not mix trunk type and crosshead pistons in same engine.

1.6	*8*	*Fluoroelastomer (Viton) caution added (S.I. 1-D-89).*
1.6	*7*	*Crosshead pistons in turbocharged industrial engines with bypass blowers (S.I. 21-D-85).*
1.6.1	*6*	*Crosshead pistons in turbocharged industrial engines with bypass blowers (S.I. 21-D-85).*
1.6.1	*6*	*Tighten connecting rod cap bolt cap bolt nuts to 40 - 45 lb-ft (54 - 61 Nm) torque.*
1.6.3	*1*	*New crosshead pistons, rings, conn rods, cylinder liners standard on all turbocharged industrial engines.*
1.6.3	*4-5*	*Caution added; Fig. 8 revised to show correct method of installing piston in liner.*
1.7.2	*1*	*New camshafts, balance weights, pulleys on turbo industrial engines with crosshead pistons and bypass blowers (S.I. 21-D-85).*
1.7.8	*1*	*Noise-dampening upper front covers on turbocharged industrial engines (S.I. 8-D-85).*
1.0	*2*	*Info. added: Welding engine cylinder heads (S.I. 34-D-85).*
1.0	*15*	*Fuel pipe nut torque specifications added (S.I. 29-D-87).*
1.0	*2*	*Info. added: Reusing crosshead piston assembly components.*
1.0	*16-18*	*Tool numbers revised, added (S.I. 13-D-85, 4-D-86, 16-D-87).*
2.1	*9*	*Revised plunger and bushing assemblies (S.I. 34-D-86).*
2.1	*12-14*	*Injector filter nut, body, cap (blued, non-blued) added (S.I. 13-D-88).*
2.1	*17*	*Endurion-coated fuel pipe nuts (S.I. 2-D-86).*
2.1	*12*	*Nylon/fiberglass injector fuel inlet filter replaced by stainless steel mesh filter (S.I. 1-D-87, 4-D-89).*

2.1	13	New round injector nut seal ring (S.I. 2-D-88).
2.1	17	Flared end fuel pipe reuse information, torque specifications added (S.I 29-D-87).
2.1.1	2,19	O-ring sealed fuel pipes on marine engines (S.I. 16-D-88).
2.1.1	8	Notice added: Do not damage injector body ring while reaming.
2.1.1	9	Revised plunger and bushing assemblies (S.I. 34-D-86).
2.1.1	10	Notice added: New valve spring and seat on high output fuel injectors (S.I. 3-D-86).
2.1.1	13	Nylon/fiberglass injector inlet filter replaced by stainless steel mesh filter (S.I. 1-D-87, 4-D-89).
2.1.1	13,15	Injector filter nut, body, cap (blued, non-blued) torque added (S.I. 13-D-88).
2.1.1	14	New round injector nut seal ring (S.I. 2-D-88).
2.1.1	18	Flared end fuel pipe reuse info., torque specifications added (S.I. 29-D-87).
2.1.1	18	Endurion-coated nuts on fuel pipes (S.I. 2-D-86).
2.1.4	1-3	New service-only injector hole tube (S.I. 14-D-85).
2.1.4	1	Info. added: Repair leaking injector tube.
2.2.	6	Notice added: Do not use Teflon tape or paste on fuel pump fittings. Fuel fitting torque added (S.I. 5-D-85).
2.3	1	Info. added: Fiberglass fuel filter element.
2.7.1	6	Engine start-up caution added.
2.7.1.1	11	Engine start-up caution added.
2.7.1.2	8	Engine start-up caution added.
2.7.1.3	1	Variable low speed-limiting speed governor conversion kits (S.I. 36-D-86).

2.7.1.3	2,5	Start-up caution added.
2.7.1.4	3	Start-up caution added.
2.7.1.5	2	Start-up caution added.
2.7.2	-	Section removed. Obsolete.
2.7.2.1	12	Start-up caution added.
2.7.2.2	8	Start-up caution added.
2.7.2.3	-	Section removed. Obsolete.
2.7.2.4	5	Start-up caution added.
2.7.2.5	12	Start-up caution added.
2.8.1.1	-	Section removed. Obsolete.
2.8.4	1-2	Woodward synchronizing motor info., wiring diagram added (S.I. 15-D-88).
2.0	3	Info. added: Injector spray tip tester J 22640).
2.0	4-5	Info. added: Check injector output; calibrator chart added (S.I. 9-D-85).
2.0	8	Info. added: Plunger/bushing and tip flow gage.
2.0	13	Fuel pipe (jumper line) info. added (S.I.2-D-85).
2.0	14,25	Fuel pipe nut torque specifications added (S.I. 16-]D-88, 29-D-87).
2.0	25	Fuel pump fitting torque added (S.I. 5-D-85).
2.0	26	Tool numbers added, revised (S.I.13-D-85, 29-D-87).
3.1	1-9	Section rewritten; minor changes.
3.4	7	Teflon-lip blower rotor shaft oil seal and spacer installation procedure added.
3.4.1	2	Blower inspection caution added.
3.4.1	2	Blower inspection caution added.

3.4.1	3	Teflon-lip blower rotor shaft oil seal and spacer installation procedure added.
3.5	3	Turbocharger safety info. added (S.I. 1-D-88).
3.5	19	Use RTV sealant to stop oil seepage on T04B turbos (S.I. 12-D-85).
3.5	22-28	TV73, TV81 Turbocharger disassembly, assembly info. added.
4.2	2	New synthetic element lube oil filter available (S.I. 30-D-87).
5	1-8	Section rewritten; cautions, notices added.
5	6	DPM cleaning solution replaces butyl cellosolve.
5	7	Info. added: Winterfronts not recommended (S.I. 8-D-89).
5	8-9	Coolant temperature control devices charts revised.
5.1	2	Use two ceramic washers when installing ceramic insert on water pump impeller; notice added (S.I. 11-D-87).
5.2.1	2	Notice added: Non-vented thermostats used in rapid warm-up cooling systems; do not use in conventional cooling system (S.I. 24-D-85).
5.2.1	1-3	Thermostat construction, operation, type, inspection info. added (S.I. 10-D-87).
5.3	1	Notice added: Winterfronts not recommended (S.I. 8-D-89).
5.5	1-2	Cautions added.
5.5	2	Zinc electrode inspection info. revised.
5.5	1	Use ethylene glycol-base antifreeze solution year-round for freeze/boilover protection.
5.6	1	Notice added on priming pump.
5.0	3-5	Info. added: Thermostat function testing (S.I. 10-D-87).

5.0	5	*Find coolant leaks with fluorescent dye, black light (S.I. 18-D-86).*
6.1.1	1	*Caution added.*
7	1	*Page rewritten, caution added.*
7.1	1	*Alternator precautions added.*
7.1	3-4	*Flange-mounted (beltless) alternator info. added.*
7.1.1	-	*Section removed. Obsolete.*
7.2	1-3	*Section rewritten; battery servicing, testing info. added.*
7.3	1	*Section rewritten.*
7.4	1-3	*Section rewritten.*
7.4.1	2,5	*Fig. 2 revised; solid state time delay switch info. added.*
7.5	-	*Section removed. Obsolete.*
7.0	1-4	*Section rewritten; minor changes.*
8.1	-	*Section removed. Obsolete.*
8.1.4	-	*Section removed. Obsolete.*
8.1.5	-	*Section removed. Obsolete.*
8.0	-	*Section removed. Obsolete.*
9.1.3	-	*Section removed.*
9.0	-	*Section removed.*
12.0	10	*Air compressor hub remover, installer tools added (S.I. 16-D-87).*
13.1	2	*Storage battery recommendation revised.*
13.1	3	*Air starter info. added.*
13.1	5	*Turbocharger caution added.*
13.1	4	*Silver 53 cold start recommendations added (S.I. 29-D-85).*
13.1.1	-	*Section removed. Obsolete.*
13.1.3	-	*Section removed. Obsolete.*

13.2	5,7,10	Silver 53 engine operating conditions added (S.I. 19-D-85).
13.2.1	4	Block oil filter bypass before initial engine start-up and dyno test of rebuilt engines (S.I. 15-D-87).
13.3	1-8	Section rewritten to reflect current lube oil and fuel recommendations (Ref. 7SE-270)
13.3	9-13	Section rewritten to reflect current coolant recommendations (Ref. 7SE-298).
14	1-8	Section rewritten. Minor changes.
14.1	1,2	Notices, cautions on barring engine added.
14.2	1	Minor changes.
14.3.1	2-6	Section rewritten. Minor changes.
14.3.2	1-11	Section rewritten. Minor changes.
14.3.3	1-3	Section rewritten. Minor changes.
14.4.1	-	Section removed. Obsolete.
14.4.2	1-4	Section rewritten. Minor changes.
14.4.3	1-5	Section rewritten. Minor changes.
14.4.4	-	Section removed. Obsolete.
14.4.5	1-8	Section completely rewritten.
14.6	1-2	Section rewritten. Minor changes.
14.7.1	1-4	Section rewritten. Minor changes.
14.7.2	-	Section removed. Obsolete.
14.14	5	Fuel modulator chart revised (S.I. 4-D-86).
15.1	1-12	Section rewritten. Minor changes. Coolant change interval, blower bypass valve maintenance interval added.
15.2	19-21	Info. added: Vehicle low power/performance at low mileage (S.I. 22-D-85).
15.2	6-7	Info. added: White smoke or misfire at idle (S.I. 17-D-84).

The following caution on air compressor usage has been added to numerous sections throughout this manual:

> ***CAUTION:** To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.*

The following service information bulletins are obsolete for the Series 53 engine service manual, but should be kept as reference for other engine service manuals:

Bulletin No.
1-D-89
4-D-89
8-D-89

The following service information bulletins are obsolete and should be removed from your files:

Bulletin No.	*Bulletin No.*	*Bulletin No.*
17-D-84		
1-D-85	*2-D-86*	*1-D-88 Rev.*
2-D-85	*3-D-86*	*2-D-88*
5-D-85	*4-D-86*	*10-D-88*
7-D-85	*5-D-86*	*12-D-88*
8-D-85	*12-D-86*	*13-D-88*
9-D-85	*18-D-86*	*15-D-88*
10-D-85	*19-D-86*	*16-D-88*
12-D-85	*28-D-86*	*19-D-88*
13-D-85	*30-D-86*	*21-D-88*
14-D-85	*33-D-86*	
18-D-85	*34-D-86*	
17-D-85	*36-D-86*	
19-D-85		
21-D-85	*1-D-87*	
22-D-85	*5-D-87*	
24-D-85	*9-D-87*	
26-D-85	*10-D-87*	
27-D-85	*11-D-87*	
28-D-85	*15-D-87*	
29-D-85	*16-D-87*	
30-D-85	*23-D-87*	
31-D-85	*30-D-87*	
32-D-85	*34-D-87*	
34-D-85	*39-D-87*	
35-D-85	*16-D-87*	
36-D-85		

CAUTION

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully observed.

Proper service and repair are important to the safety of the service technician and the safe, reliable operation of the engine. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part. Do not use a replacement part of lesser quality.

The service procedures recommended by Detroit Diesel Corporation and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specially designed for the purpose.

Accordingly, anyone who intends to use a replacement part, service procedure or tool, which is not recommended by Detroit Diesel Corporation, must first determine that neither his safety nor the safe operation of the engine will be jeopardized by the replacement part, service procedure or tool selected.

It is important to note that this manual contains various "Cautions" and "Notices" that must be carefully observed in order to reduce the risk of personal injury during service or repair or the possibility that improper service or repair may damage the engine or render it unsafe. It is also important to understand that these "Cautions" and "Notices" are not exhaustive, because it is impossible for Detroit Diesel Corporation to warn of all the possible hazardous consequences that might result from failure to follow these instructions.

FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the basic Series 53 Detroit Diesel Engines.

Full benefit of the long life and dependability built into these engines can be realized through proper operation and maintenance. Of equal importance is the use of proper procedures during engine overhaul.

Personnel responsible for engine operation and maintenance should study the sections of the manual pertaining to their particular duties. Similarly, before beginning a repair or overhaul job, the serviceman should read the manual carefully to familiarize himself with the parts or subassemblies of the engine with which he will be concerned.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. This publication is revised and reprinted periodically. It is recommended that users contact an authorized *Detroit Diesel Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

TABLE OF CONTENTS

• SCOPE AND USE OF THE MANUAL

This manual covers the basic Series 53 Diesel Engines built by the Detroit Diesel Corporation. Complete instructions on operation, adjustment (tune-up), preventive maintenance and lubrication, and repair (including complete overhaul) are covered. The manual was written primarily for persons servicing and overhauling the engine and, in addition, contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all Series 53 engines and, therefore, apply to all Inline and Vee models.

The manual is divided into numbered sections. The first section covers the engine (less major assemblies). The following sections cover a complete system such as the fuel system, lubrication system or air system. Each section is divided into subsections which contain complete maintenance and operating instructions for a specific subassembly on the engine. For example, Section 1, which covers the basic engine, contains subsection 1.1 pertaining to the cylinder block, subsection 1.2 covering the cylinder head, etc. The subjects and sections are listed in the Table of Contents on the preceding page. Pages are numbered consecutively, starting with a new Page 1 at the beginning of each subsection. The illustrations are also numbered consecutively, beginning with a new Fig. 1 at the start of each subsection.

Information regarding a general subject, such as the lubrication system, can best be located by using the Table of Contents. Opposite each subject in the Table of Contents is a section number which registers with a tab printed on the first page of each section throughout the manual. Information on a specific subassembly or accessory can then be found by consulting the list of contents on the first page of the section. For example, the cylinder liner is part of the basic engine. Therefore, it will be found in Section 1. Looking down the list of contents on the first page of Section 1, the cylinder liner is found to be in subsection 1.6.3. An Alphabetical Index at the back of the manual has been provided as an additional aid for locating information.

SERVICE PARTS AVAILABILITY

Genuine Detroit Diesel service parts are available from authorized Detroit Diesel distributors and service dealers throughout the world. A complete list of all distributors and dealers is available in the Worldwide Distributor and Dealer Directory, 6SE280. This publication can be ordered from any authorized distributor.

CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabular form at the end of each section throughout the manual. It should be specifically noted that the "New Parts" clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the paragraph entitled *Inspection* under *General Procedures* in this section.

Bolt, nut and stud torque specifications are also listed in tabular form at the end of each section.

PARTS REPLACEMENT

Before installing a new or used part, check it thoroughly to make sure it is the proper part for the job. The quality of the replacement part must be equivalent to the quality of the original Detroit Diesel component being replaced and must meet DDC specifications for new or reusable parts.

Parts must also be clean and not physically damaged or defective. For example, bolts and bolt hole threads must not be damaged or distorted. Gasketing must have all holes completely punched through with no residual gasket material left clinging to the top or bottom. Flatness and fit specifications in the service manual must be strictly adhered to.

CAUTION: Failure to inspect parts thoroughly before installation, failure to install the proper parts, or failure to install parts properly can result in component or engine malfunction and/or damage and may also result in personal injury.

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Two–Cycle Principle

In the two–cycle engine, intake and exhaust take place during part of the compression and power strokes respectively as shown in Fig. 1. In contrast, a four–cycle engine requires four piston strokes to complete an operating cycle.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Fig. 1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Fig. 1 (compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Fig. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about half way down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a "two–stroke cycle".

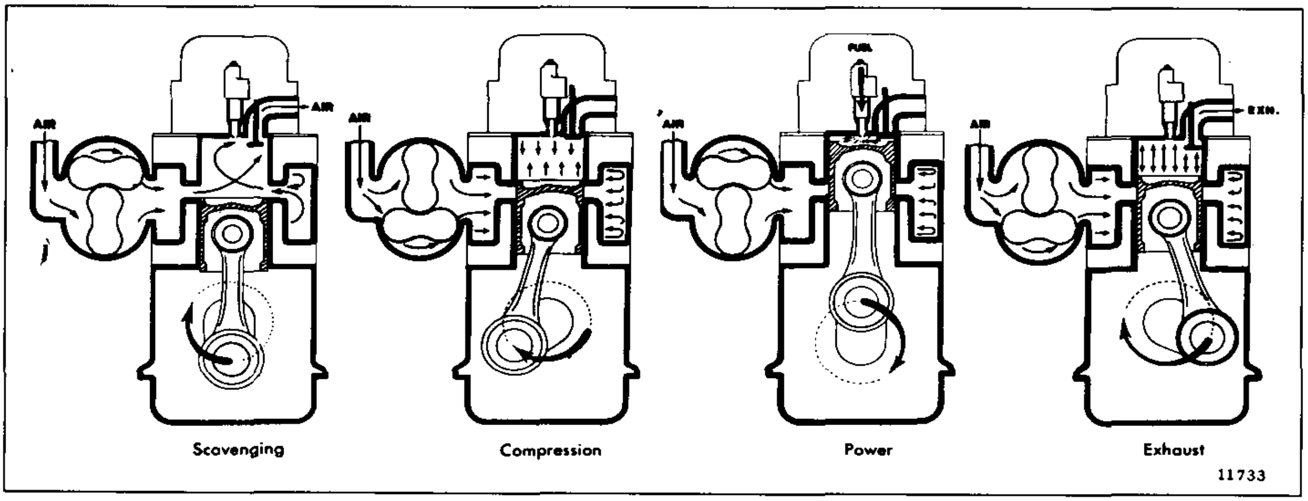


Fig. 1 – The Two Stroke Cycle (In-Line Models)

GENERAL DESCRIPTION

The two–cycle diesel engines covered in this manual have the same bore and stroke and many of the major working parts are interchangeable.

The in–line engines, including the inclined marine models, include standard accessories such as the blower, water pump, governor and fuel pump, which, on some models, may be located on either side of the engine regardless of the direction the crankshaft rotates. Further flexibility in meeting installation requirements is achieved with the cylinder head which can be installed to accommodate the exhaust manifold on either side of the engine.

The V–type engines use many in–line engine parts, including the 3–53 and 4–53 cylinder heads. The blower is mounted on top of the engine between the two banks of cylinders and is driven by the gear train. The governor is mounted on the rear end of the 6V–53 blower.

The meaning of each digit in the model numbering system is shown in Figs. 2 and 3. The letter L or R indicates left or right–hand engine rotation as viewed from the front of the engine. The letter A,B,C or D designates the blower and exhaust manifold location on the In–line engines as viewed from the rear of the engine while the letter A or C designates the location of the oil cooler and starter on the V–type engines.

Each engine is equipped with an oil cooler (not required on certain two–cylinder models), full–flow oil filter, fuel oil strainer and fuel oil filter, and air cleaner or silencer, governor, heat exchanger and raw water pump or fan and radiator, and a starting motor.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings and to other moving parts. A rotor–type pump on in–line or 6V engines draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the camshaft bearings and up through the rocker arm assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

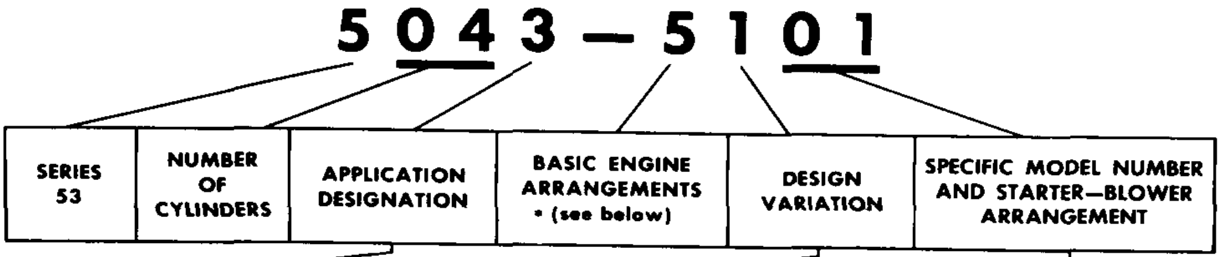
Coolant is circulated through the engine by a centrifugal–type water pump. Heat is removed from the coolant, which circulates in a closed system, by the heat exchanger or radiator. Control of the engine temperature is accomplished by thermostat(s) which regulate the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the fuel strainer by a gear–type fuel pump. It is then forced through a filter and into the fuel inlet manifold in the cylinder head(s) and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner or silencer.

Engine starting is provided by an air or an electrical starter. The electric starting motor is engerized by a storage battery. A battery–charging alternator serves to keep the battery charged.

Engine speed is regulated by a mechanical or hydraulic type engine governor, depending upon the engine application.



APPLICATION DESIGNATION

5042-5100	MARINE
5043-5100	FAN TO F/W—INDUSTRIAL
5044-5100	POWER-BASE
5045-5100	GENERATOR
5047-5100	FAN TO F/W—VEHICLE

DESIGN VARIATION

5043-5000	"N" ENGINE
5043-5100	2 VALVE HEAD
5043-5200	4 VALVE HEAD
5042-2302	TURBOCHARGER

STARTER—BLOWER ARRANGEMENT

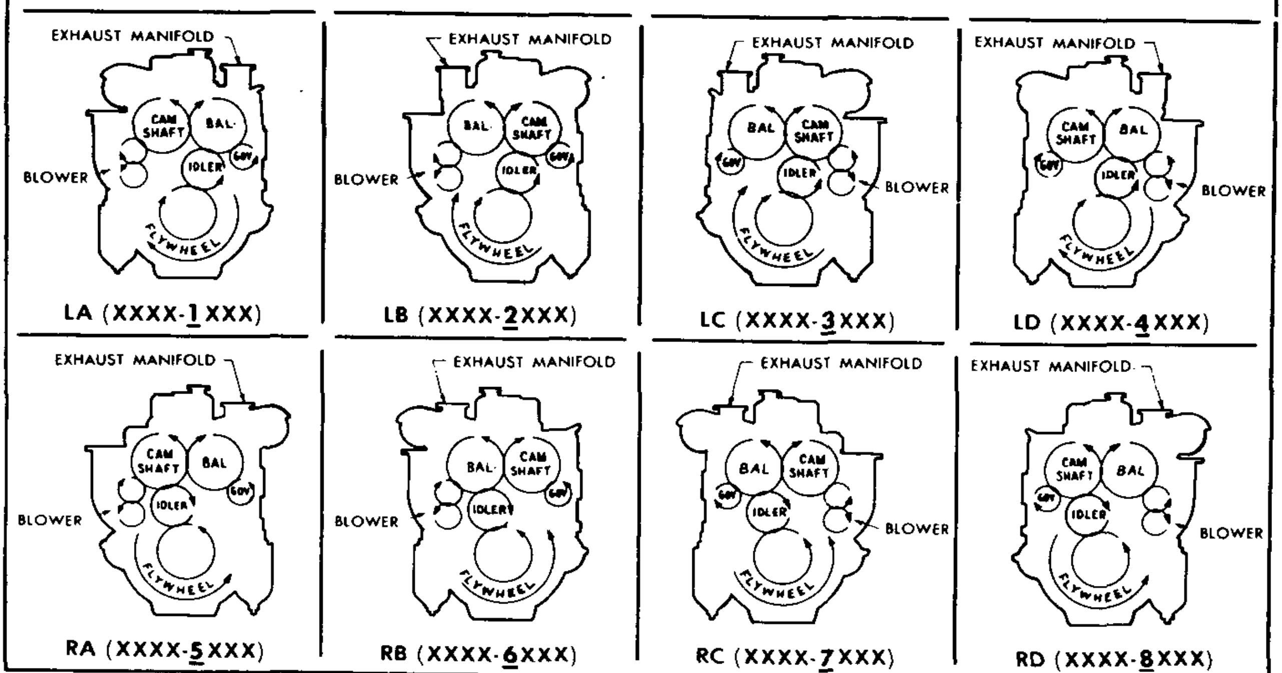
Odd number in last digit designates starter opposite blower.

Even number in last digit designates starter same side as blower.

*** 2, 3, 4-53 BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A-B-C-D designates location of exhaust manifold and blower as viewed from the flywheel end of the engine.



ALL ABOVE VIEWS FROM REAR (FLYWHEEL) END OF ENGINE 12223

Fig. 2 – In–line Engine Model Description, Rotation and Accessory Arrangements

5 0 6 3 — 5 2 0 0

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENT * *(see below)*	DESIGN VARIATION	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATION

5062-3000 MARINE
5063-5200 FAN to F/W-INDUSTRIAL
5064-5200 POWER-BASE
5065-5200 GENERATOR
5067-5040 FAN to F/W VEHICLE
5082-5000 MARINE
5083-5000 FAN to F/W INDUSTRIAL
5087-5040 FAN to F/W VEHICLE

DESIGN VARIATION

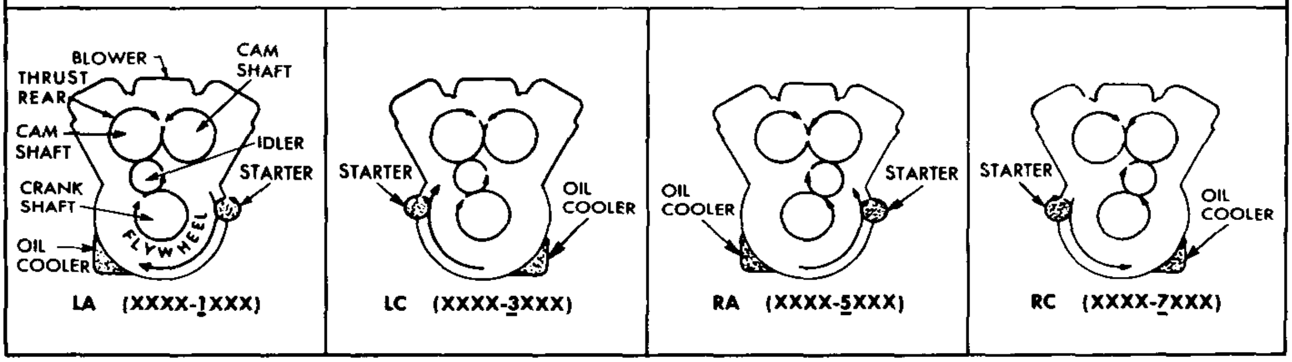
5062-3000 "N" ENGINE
5063-5200 4 VALVE HEAD
5067-5340 TURBOCHARGER

*** BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A and C designates location of starter and oil cooler as viewed from the flywheel end of the engine.

Cylinder Bank: Left and right cylinder banks are determined from the flywheel end of the engine.



ALL ABOVE VIEWS FROM REAR FLYWHEEL END OF ENGINE 11783

Fig. 3 – V–Type Engine Model Description, Rotation and Accessory Arrangement

GENERAL SPECIFICATIONS

	2-53*	3-53	4-53	6V-53	8V-53*
Type	2 Cycle	2 Cycle	2 Cycle	2 Cycle	2 Cycle
Number of cylinders	2	3	4	6	8
Bore (inches)	3.875	3.875	3.875	3.875	3.875
Bore (mm)	98	98	98	98	98
Stroke (inches)	4.5	4.5	4.5	4.5	4.5
Stroke (mm)	114	114	114	114	114
Compression ratio (normal) (standard engine)	17 to 1	17 to 1	17 to 1	17 to 1	17 to 1
Compression ratio (normal) ("T" engines)	—	18.7 to 1	18.7 to 1	18.7 to 1	—
Compression ratio (normal) ("N" engines)	—	21 to 1	21 to 1	21 to 1	21 to 1
Total displacement – cubic inches	106	159	212	318	424
Total displacement – liters	1.74	2.61	3.48	5.22	6.96
Number of main bearings	3	4	5	4	5

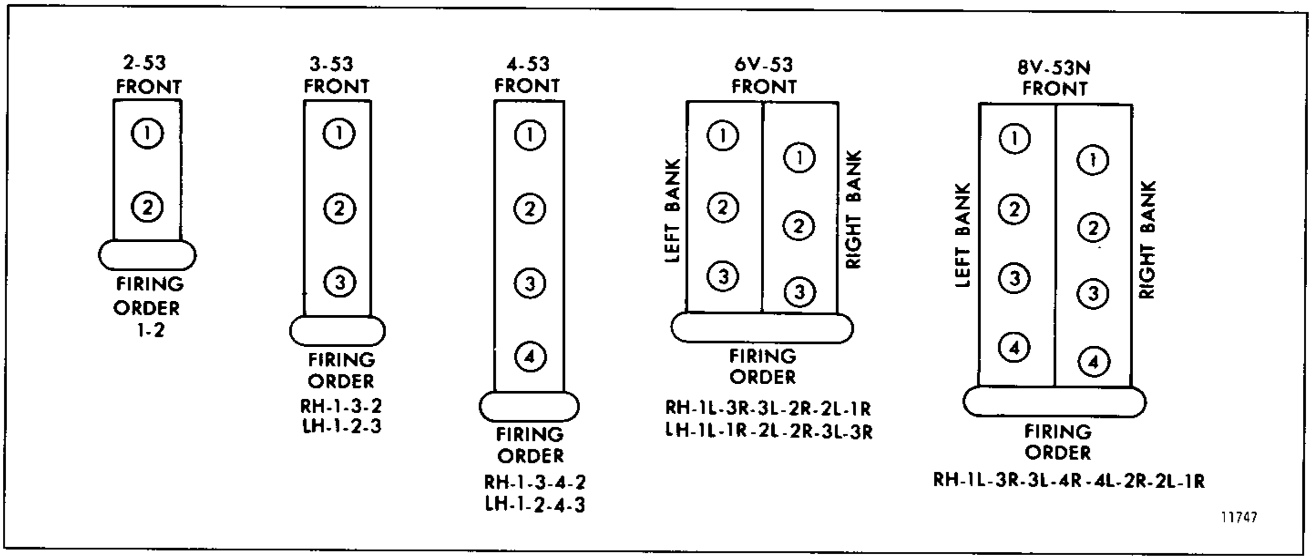


Fig. 4 – Cylinder Designation and Firing Order

*In–line 2-53 and 8V-53 engine models are no longer manufactured.

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

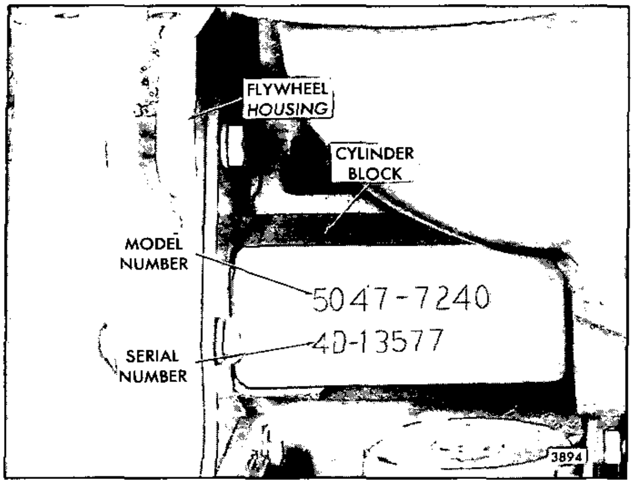


Fig. 5 – Typical Model and Serial Numbers as Stamped on Cylinder Block (In–Line Engine)

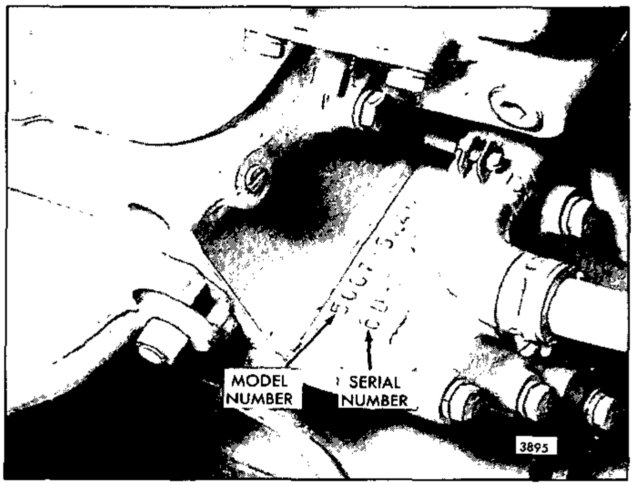


Fig. 6 – Typical Model and Serial Numbers as Stamped on Cylinder Block (6 and 8V Engines)

On the in–line engines, the model number and serial number are stamped on the right–hand side of the cylinder block in the upper rear corner (Fig. 5). The model number and serial number on the V–type engines are located on the top right–hand front corner of the cylinder block, as viewed from the rear of the engine (Fig. 6).

• Option Plate (Metal Labels)

An option plate, attached to the valve rocker cover, carries the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 7). Engines built in Brazil have a serial number prefix of 3DB (three cylinder), 4DB (four cylinder) or 6DB (six cylinder).

On–highway vehicle engines also carry an exhaust emission certification label, separate from the option plate and it is mounted permanently in the option plate retainer. The current label includes information relating to an engine family for the maximum fuel injector size and maximum speed. *Due to Federal regulations, the exhaust emission plate should not be removed from the rocker cover.* Refer to Section 14 for further information regarding emission regulations.

With any order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups of parts used on an engine are standard for the engine model unless otherwise listed on the option plate.

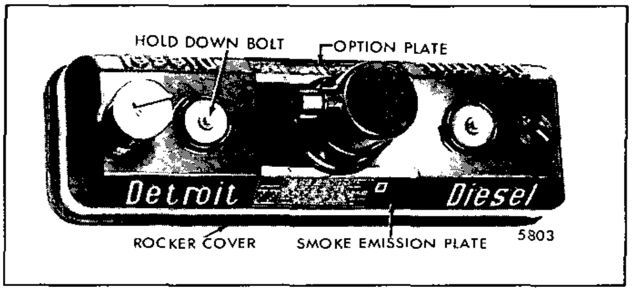
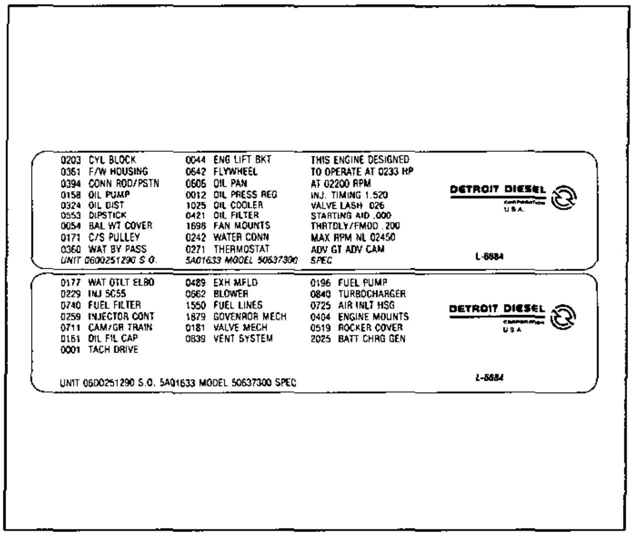


Fig. 7 – Option Plate



0203 CYL BLOCK	0044 ENG LIFT BKT	THIS ENGINE DESIGNED
0361 F/W HOUSING	0642 FLYWHEEL	TO OPERATE AT 0233 HP
0394 CONN ROD/PSTN	0606 OIL PAN	AT 02200 RPM
0158 OIL PUMP	0012 OIL PRESS REG	INJ. TIMING 1.520
0324 OIL DIST	1025 OIL COOLER	VALVE LASH 026
0553 DIPSTICK	0421 OIL FILTER	STARTING AID .000
0054 BAL WT COVER	1698 FAN MOUNTS	THRTDLY/FMOD .200
0171 C/S PULLEY	0242 WATER CONN	MAX RPM NL 02450
0360 WAT BY PASS	0271 THERMOSTAT	ADV GT ADV CAM
UNIT 0600251290 S O.	*5A01633 MODEL 50637300*	*SPEC*

DETROIT DIESEL U.S.A.
L-6684

0177 WAT OTLT ELBO	0489 EXH MFLD	0196 FUEL PUMP
0229 INJ 5C55	0662 BLOWER	0840 TURBOCHARGER
0740 FUEL FILTER	1550 FUEL LINES	0725 AIR INLT HSG
0259 INJECTOR CONT	1879 GOVENROR MECH	0404 ENGINE MOUNTS
0711 CAM/GR TRAIN	0181 VALVE MECH	0519 ROCKER COVER
0161 OIL FIL CAP	0839 VENT SYSTEM	2025 BATT CHRG GEN
0001 TACH DRIVE		

UNIT 06D0251290 S.O. 5A01633 MODEL 50637300 SPEC

DETROIT DIESEL U.S.A.
L-6684

• Fig. 8 – Typical Option Label

• Option Plate (Paper Labels)

A new paper/laminate engine option label (Fig. 8) has replaced the metal option plate. In conjunction with the new option label, the following paper/laminate labels are also being used: **bar code labels** for engine serial number and customer specification number; **emissions label** (when applicable) and **disclaimer label**.

Distributors will provide their own label(s) in order to notify the customer of any distributor–made changes to Detrot Diesel–manufactured engines. Distributor–typed label(s) will indicate the distributor name, address and the group/type revisions that reflect their changes to engines as originally manufactured by Detroit Diesel.

Attaching Lables

Labels must be placed on rocker covers. Labels are designed to fit in the same space provided for the former stamped or current cast rocker cover option plate holder. Replacement option labels can be placed directly over existing option labels. *Make certain the labels are applied to clean, dry, oil–free surfaces to assure adhesion and retention.* Laminate should completely cover the label to provide a good seal.

The option plate holder on cast rocker covers is held to the cover by rivets in blind holes. Therefore, the option plate holder can be removed and the labels applied directly to the rocker covers. The option plate holder on stamped rocker covers is retained by spot welding. This option plate holder should not be removed, since it can leave open holes which will allow the leakage of lube oil.

> **NOTICE:** Extreme heat from components such as turbocharger exhaust piping can cause the labels to darken, discolor or deteriorate over a period of time. Therefore, labels should be installed at alternate rocker cover locations.

GENERAL PROCEDURES

In many cases, a Service Technician is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, thereby saving the expense of a new part. Exchange assemblies such as injectors, fuel pumps, water pumps and blowers are also desirable service items.

Various factors such as the type of operation of the engine, hours in service and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble–free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, coolant, and fuel. On engines cooled by a heat exchanger, the fresh water system and raw water system must both be drained. Lubricating oil should also be drained from any transmission attached to the engine.

CAUTION: To avoid being burned by the hot liquid, allow the engine to cool before draining the coolant.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be supported on a level surface; then the various subassemblies should be removed from the engine.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks, or a parts dolly.

CLEANING

Before removing any of the subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under *Clean Cylinder Block* in Section 1.1; any special cleaning procedures will be mentioned in the text wherever required.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provision made for heating the cleaning solution to 180–200°F (82–90°C).

Fill the tank with a commercial heavy–duty solvent which is heated to the above temperature. Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector.

The guiding factors in determining the usability of worn parts, which are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and/or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should be equipped with standard gages such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other defects.

ASSEMBLY

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of the proper equipment and tools make the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment and space will be repaid many times.

Keep the working space, the equipment, tools and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and subassemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be recleaned.

When assembling an engine or any part thereof, refer to the table of torque specifications at the end of each section for proper bolt, nut and stud torques.

To ensure a clean engine at time of rebuild, it is important that any plug, fitting or fastener (including studs) that intersects with a through hole and comes in contact with oil, fuel or coolant must have a sealer applied to the threads.

A number of universal sealers are commercially available. It is recommended that Loctite J 26558-97 *pipe sealer with teflon,* or equivalent, be used.

> **NOTICE:** Certain plugs, fittings and fasteners available from the Parts Depot already have a sealer applied to the threads. This pre-coating will not be affected when the pipe sealer with teflon is also applied.

The sealer information above must not be confused with International Compound No. 2, which is a lubricant applied before tightening certain bolts. Use International Compound No. 2 only where specifically stated in the manual.

.CAUTIONS

WORK SAFELY

The service procedures recommended by Detroit Diesel Corporation and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specially designed for the purpose.

Accordingly, anyone who intends to use a replacement part, service procedure or tool, which is not recommended by Detroit Diesel Corporation, must first determine that neither his safety nor the safe operation of the engine will be jeopardized by the replacement part, service procedure or tool selected.

It is important to note that this manual contains various "Cautions" and "Notices" that must be carefully observed in order to reduce the risk of personal injury during service or repair or the possibility that improper service or repair may damage the engine or render it unsafe. It is also important to understand that these "Cautions" and "Notices" are not exhaustive, because it is impossible for Detroit Diesel Corporation to warn of all the possible hazardous consequences that might result from failure to follow these instructions.

A service technician can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid such a misfortune take these precautions before starting to work on an engine:

1. Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.
2. Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no–fuel position. The possibility of the engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle is minimized.

Some Safety Precautions to Observe When Working on the Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.
2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.
3. • The front engine lifter bracket is not designed to lift more than the basic engine. When lifting the engine with marine gear or generator attached, the proper hook points on the engine cradle or mounting rails *must* be used. Do not use the front lifter bracket alone under these circumstances. Failure to observe this precaution can result in personal injury and/or serious engine damage.
4. Always use caution when using power tools.
5. • When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury. Always wear adequate eye protection (safety glasses, safety face shield) when working with compressed air.
6. • To avoid possible personal injury when working with chemicals, steam and/or hot water, wear adequate protective clothing (face shield, rubber apron, gloves, boots, etc), work in a well ventilated area, and exercise caution.
7. • Avoid the use of carbon tetrachloride, carbon disulfide, methylene, chloride, perchloroethylene and trichloroethylene as cleaning agents because of harmful vapors they release. Use 1,1,1–Trichloroethane. However, while less toxic than other chlorinated solvents, use it with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield and an apron. Follow chemical manufacturer's use and safety recommendations.

   Exercise caution against chemical burns when using acids (Oxalic, phosphoric and nitric) and alkaline cleaners. Use protective gloves, goggles or face shield and an apron.

   CAUTION: Mineral spirits or mineral spirits based solvents are highly flammable. They must be stored and used in "No Smoking" areas away from heat, sparks and open flames.
8. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build–up inside the tank is sufficient.
9. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.
10. • Failure to inspect parts thoroughly before installation, failure to install the proper parts, or failure to install parts properly can result in component or engine malfunction and/or damage and may also result in personal injury.
11. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.

• FABRICATING, ALTERING, REMOVING AND DISPOSING OF GASKETS

Many gasket materials contain bonded asbestos, which in itself presents no health hazard when handled properly. A health hazard may exist, however, if the asbestos in such materials is liberated and becomes airborne. This may occur if gaskets are fabricated or altered using the following improper methods: *drilling, grinding, saw cutting* or using practically all types of power operated machines and hand tools.

Gasket manufacturers and industrial hygienists prescribe specific methods for handling gasket material. The following guidelines are based on their recommendations. Detroit Diesel recommends that these guidelines be followed when fabricating or altering any gaskets.

1. Unless it is known otherwise, treat all gasket material as though it contains asbestos.

CAUTION

CONTAINS ASBESTOS

AVOID OPENING OR BREAKING CONTAINER

BREATHING ASBESTOS IS HAZARDOUS TO YOUR HEALTH

DATE FILLED ______________

Fig. 9 – Caution Label

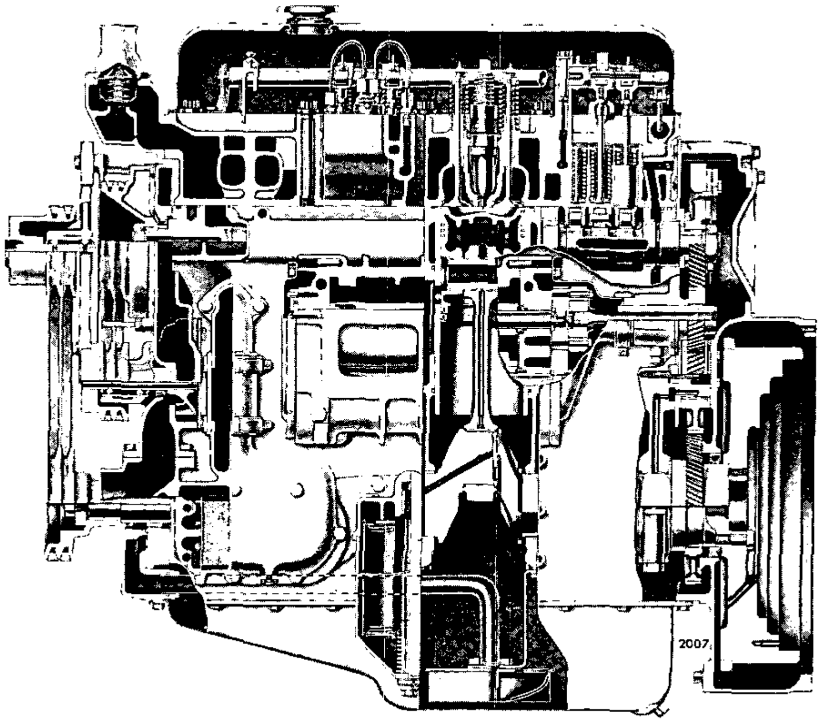
2. When cutting strips or blocks from sheets (blanking), hand cut with scissors, knife or paper cutter. Avoid creating dust.
3. Form outside dimensions with a punch die or hand cut with scissors, knife or compass.
4. For internal hubs use a punch die, hand cut with scissors, knife or compass, or punch by hand with a ballpeen hammer or ball bearing.
5. When stripping gaskets from parts, do not grind or file off the material or abraid it off with a wire brush or wheel. Use a putty knife to remove the gasket after it has been wetted with water or oil.
6. After fabricating or altering a gasket, clean the area to remove any particles which may have been generated. This should be done by wiping the area with a rag wetted with water or a water–based detergent. If large areas need to be cleaned, remove gasket dust and debris using an "HEPA" (High Efficiency Particulate Arrestor) vacuum cleaner. Do not clean the area by blowing with compressed air or brushing.

Place the rags containing the waste and any scrap gasket material in an impervious container labeled with the OSHA (Occupational Health and Safety Administration) designated caution (Fig. 9) and dispose of it in a solid waste disposal facility (land fill) which will accept asbestos material. Heavy plastic garbage bags (6 mills thick), each sealed separately, or other closed and impermeable container may be used.

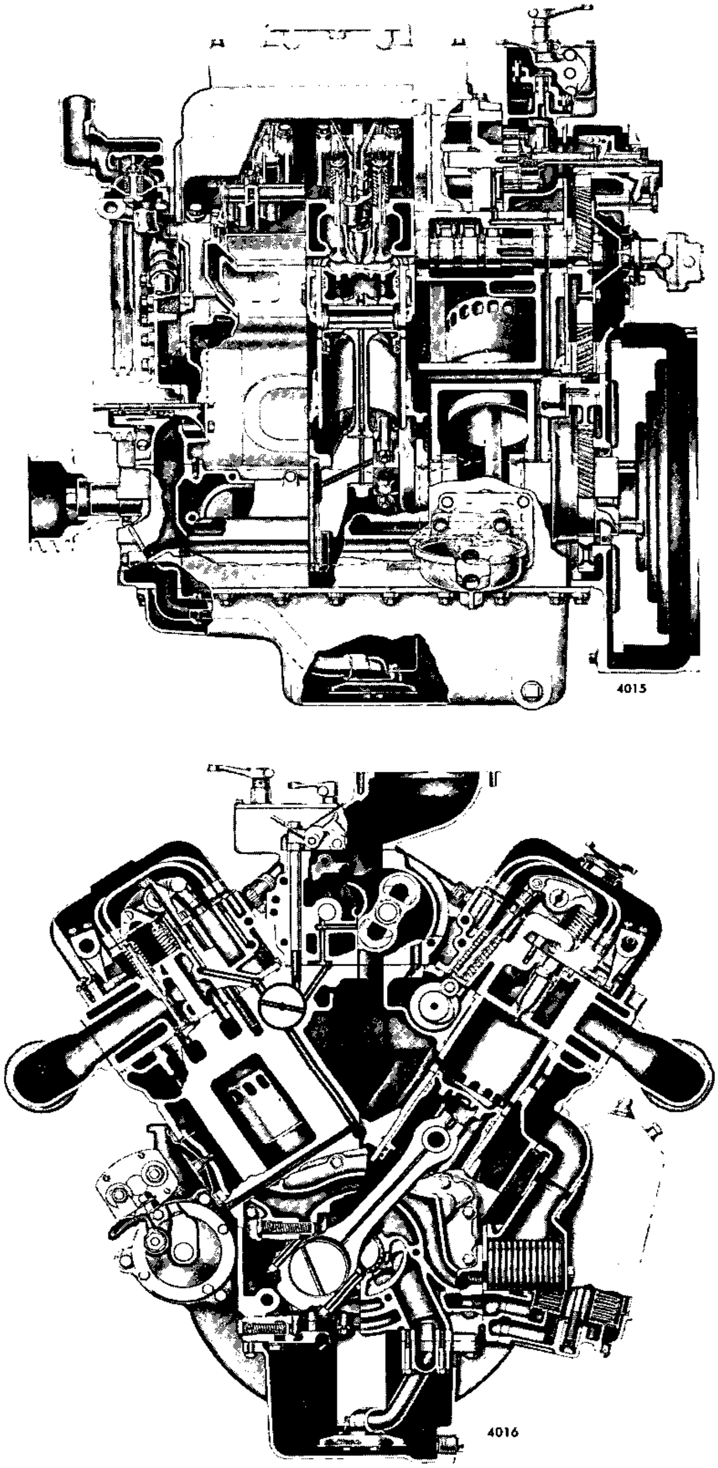
• Fluoroelastomer (Viton) Caution

Under normal design conditions, fluoroelastomer (Viton) parts, such as O–rings and seals, are perfectly safe to handle. However, a potential hazard may occur if these components are raised to a temperature above 600°F (316°C) such as during a cylinder failure or engine fire. At temperatures above 600°F (316°C) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

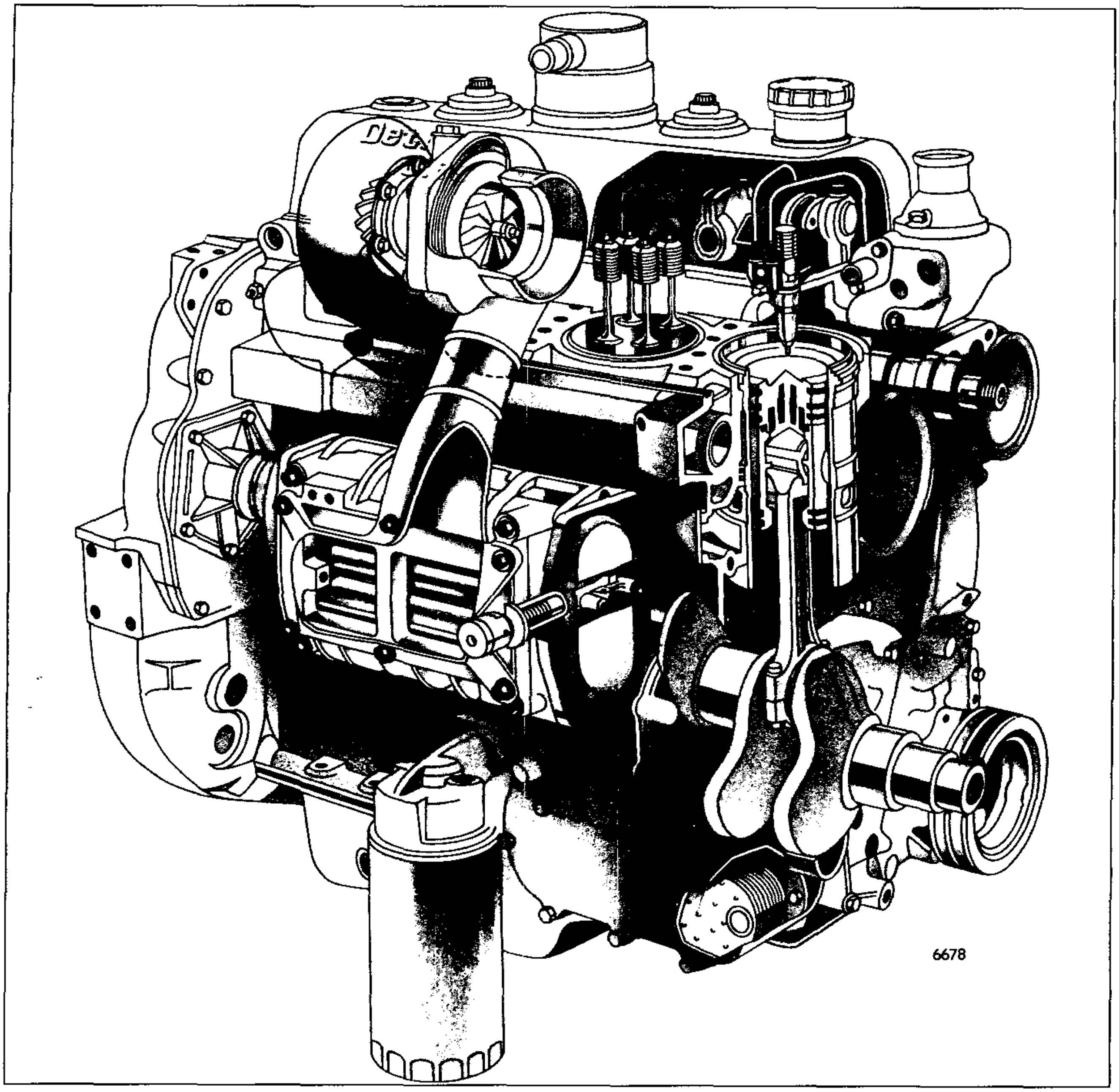
CAUTION: To avoid personal injury, wear goggles or a faceplate and neoprene or PVC gloves when handling fluoroelastomer O–rings or seals which have been degraded by excess heat. Make sure engine parts have cooled before handling them. If hydrogen fluoride condensate is expected, wash equipment and parts well with lime water (calcium hydroxide solution) before reusing. Discard gloves after handling degraded fluoroelastomer.



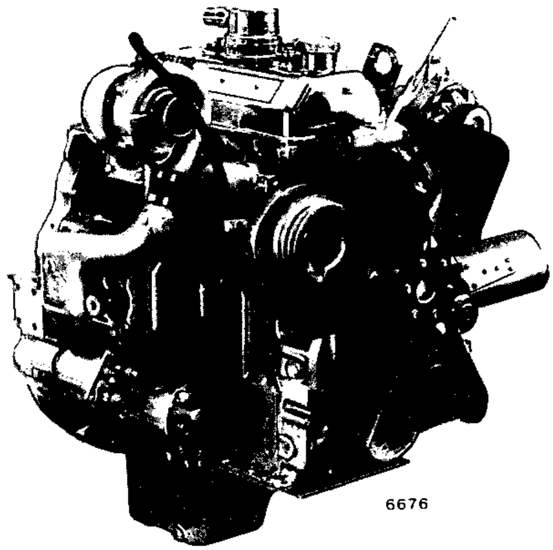
Cross Section of a Typical In-Line Engine



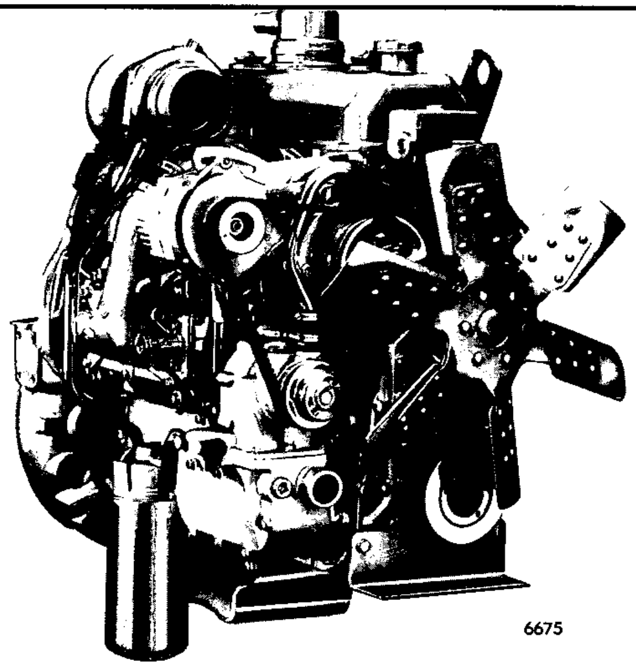
Cross Section of a 6V-53 Engine



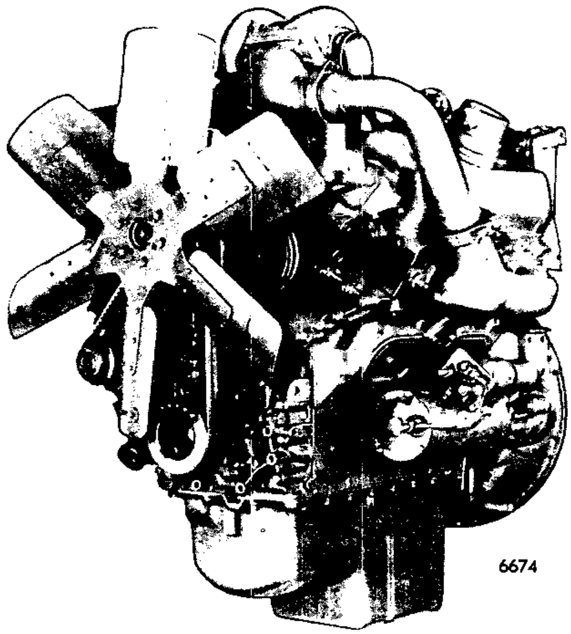
Three-Quarter Cutaway View of In-line 4-53 Engine



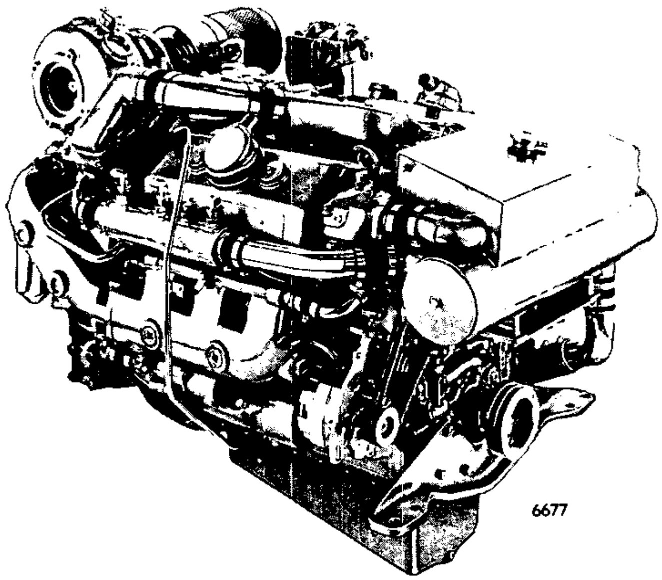
Typical Fan-to-Flywheel 3-53 Engine



Typical Fan-to-Flywheel 4-53 Engine



Typical 6V-53 Fan-to-Flywheel Industrial Engine



Typical 6V-53 Marine Propulsion Engine

SECTION 1

ENGINE (less major assemblies)

CONTENTS

CYLINDER BLOCK

The cylinder block serves as the main structural part of the engine (Figs. 1 and 2). Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load. Cylinder blocks for the two, three and four cylinder In–line engines are identical in design and dimensions except for length.

The block is bored to receive replaceable wet–type cylinder liners. On the In–line and 6V–53 cast iron cylinder blocks, a water jacket surrounds the upper half of each cylinder liner. On the 6V–53 aluminum and the former 8V–53 cast iron cylinder blocks, a water jacket also surrounds the lower half of each cylinder liner. The water jacket and air box are sealed off by two seal rings compressed between the liner and grooves in the block (Figs. 3, 4 and 5).

An air box surrounding the lower half of the cylinder liners conducts the air from the blower to the air inlet ports in the cylinder liners. An opening in the side of the block opposite the blower on the In–line engines and air box openings in both sides of the block on the V–type engines provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners.

Due to the higher air box pressure required for the 6V–53 turbocharged engines, thicker gage steel air box covers, polyacrylic rubber and cork gaskets and ductile iron clamps are used.

The camshaft and balance shaft bores are located on opposite sides near the top of the In–line engine block. On the V–type engine, the camshaft bores are located on the inner side of each cylinder bank near the top of the block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line–bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

The top surface of the In–line block and each cylinder bank of the V–block is grooved to accommodate a block–to–head oil seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings (Fig. 6). In addition, the V–type engine block is grooved around the air inlet opening, between the cylinder banks, to accommodate a blower–to–block seal ring.

Each cylinder liner is retained in the block by a flange at its upper end, which seats in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

When the cylinder head is installed, the gaskets and seal rings compress sufficiently to form a tight metal–to–metal contact between the head and the block.

The In–line cylinder blocks have been revised to improve the breathing characteristics and increase the flow of the lubricating oil returning from the cylinder head to the engine oil sump by the addition of two vertical oil passages directly under the camshaft and balance shaft at the front end of the cylinder block (Fig. 8). Cylinder blocks with the vertical oil passages were used in engines beginning with serial numbers 2D–4010, 3D–117 and 4D–348.

The 8V–53 cylinder block was revised, effective with engine serial number 8D–2304, to provide improved scavenging and crankcase breathing by the addition of oil drains at the front corners of the cylinder block. The 8V–53 service cylinder block incorporates an oil drain at each corner of the block.

New service replacement cylinder block assemblies include the main bearing caps, bolts and washers and the camshaft bearings (bushings). The dowels and the necessary plugs are also included.

• In order to standardize, naturally aspirated engine cylinder blocks were replaced by turbocharged engine blocks effective with unit serial numbers 3D0186921, 4D0206687, and 6D0233385. Only the turbo blocks are serviced.

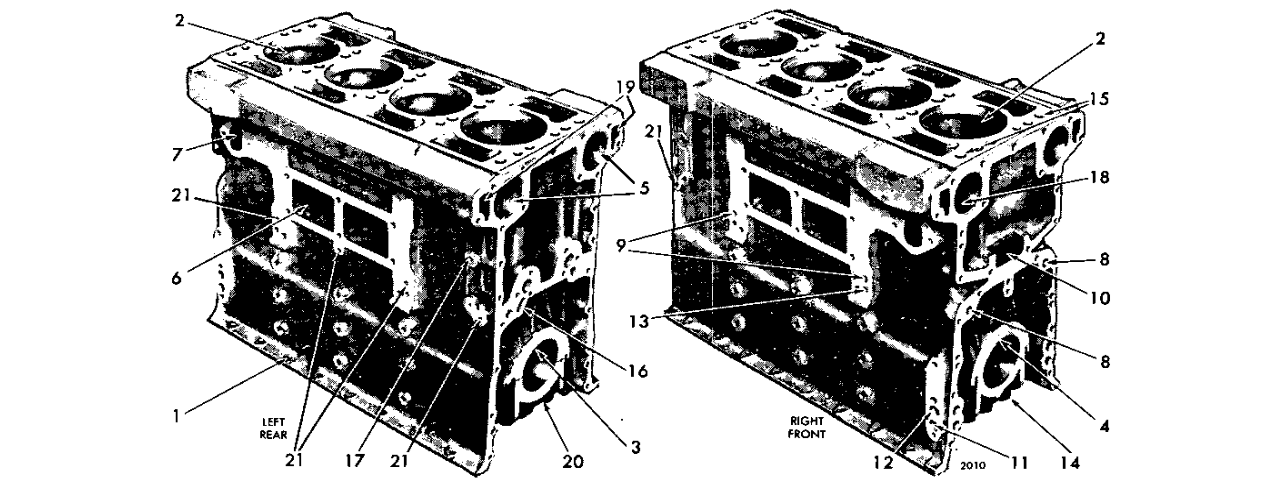
Cylinder blocks formerly manufactured in Brazil had larger oil passages for greater oil flow, reinforced main struts for added support, the rear of the cylinder block is closed in and oil grooves in the upper main bearing bore.

> **NOTICE:** A Brazilian manufactured block can be used to service a naturally aspirated (N) engine or a turbocharged engine. However, a U.S. manufactured cylinder block *must not* be used to service a turbocharged engine.

On 2 cylinder "C" and "D" engine cylinder blocks, the side opposite the blower is cast solid. The air box inspection is accomplished by removing the blower. Service blocks will continue to be cast open on both sides since the above does not apply to the "A" engines.

Since the cylinder block is the main structural part of the engine, the various subassemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 10) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90° or 180° where it is locked in place and then, if desired, tipped back with either end or the oil pan side up.



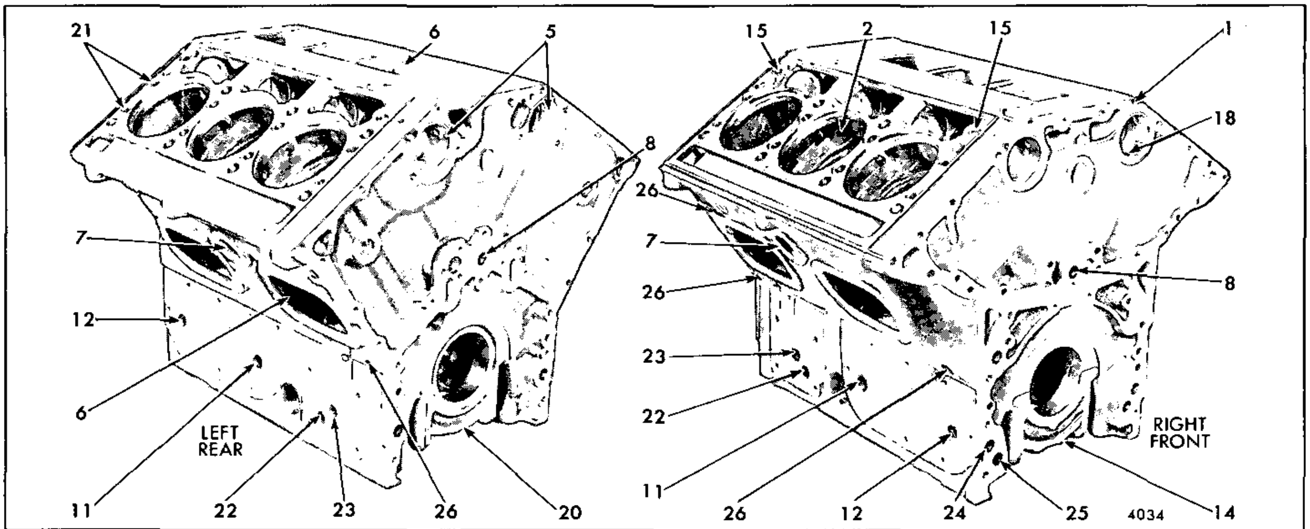
1. Cylinder Block
2. Bore for Cylinder Liner
3. Support—Upper Main Bearing (Rear)
4. Support—Upper Main Bearing (Front)
5. Bore—Cam or Balance Shaft
6. Air Box
7. Water Passage from Oil Cooler to Block
8. Oil Gallery (Main)
9. Oil Gallery (to Blower)
10. Oil Drain from Front Cover
11. Oil Passage to Oil Cooler
12. Oil Passage from Oil Cooler
13. Oil Drain from Blower
14. Cap—Main Bearing (Front)
15. Oil Passage to Cylinder Head (from Camshaft)
16. Oil Passage (Idler Gear Bearing)
17. Water Drain
18. Oil Gallery to Camshaft or Balance Shaft
19. Oil Drain from Cylinder Head
20. Cap—Main Bearing (Rear)
21. Oil Pressure Take–Off Opening

Fig. 1 – Cylinder Block (4–53 Cylinder Block Shown)

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the transmission or other driven mechanism. Details of this procedure will vary from one application to another. However, the following steps will be necessary:

1. Drain the cooling system.
2. Drain the lubricating oil.
3. Disconnect the fuel lines.
4. Remove the air silencer or air cleaner and mounting bracket.
5. Remove the turbocharger, if used.
6. Remove the blower on In–line engines.
7. Disconnect the exhaust piping and remove the exhaust manifold(s).
8. Disconnect the throttle controls.
9. Disconnect and remove the starting motor, battery–charging generator or alternator and other electrical equipment.
10. Remove the air compressor, if used.
11. Remove the radiator and fan guard or the heat exchanger and other related cooling system parts.
12. Remove the air box drain tubes and fittings.
13. Remove the air box covers.
14. Disconnect any other lubricating oil lines, fuel lines or electrical connections.
15. Separate the engine from the transmission or other driven mechanism.
16. Remove the engine mounting bolts.
17. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (Fig. 9).



1. Cylinder Block
2. Bore for Cylinder Liner
5. Camshaft Bore
6. Air Box
7. Water Passage from Oil Cooler to Block
8. Oil Gallery (Main)
11. Oil Passage to Oil Cooler
12. Oil Passage from Oil Cooler
14. Cap—Main Bearing (Front)
15. Oil Passage to Cylinder Head
18. Oil Gallery to Camshaft
20. Cap—Main Bearing (Rear)
21. Water Passage to Cylinder Head
22. Oil Passage to Filter from Pump
23. Oil Passage from Filter to Oil Cooler
24. Oil Passage to Main Gallery via Front Cover
25. Oil Passage from Oil Pump to Filter
26. Oil Pressure Take–Off Opening

Fig. 2 – Cylinder Block (6V–53 Cast Iron Cylinder Block Shown)

To prevent bending of the engine lifter brackets the lifting device should be adjusted so the lifting hooks are vertical. *To ensure proper weight distribution all engine lifter brackets should be used to lift the engine.*

- **NOTICE:** Do not lift an engine by the webs in the air inlet opening of the cylinder block. The webs are not strong enough to support the weight of the block.

18. Place the side of the cylinder block against the adaptor plate on the overhaul stand (Fig. 10). Use adaptor plate J 7622–01 (In–line engine), J 8683 (6V–53 engine) or J 21966 (8V–53 engine) with overhaul stand J 29109.

19. Align the bolt holes in the adaptor plate with the holes in the cylinder block. Then, install the 3/8″–16 and 5/16″–18 bolts, with a flat washer under the head of *each bolt, and tighten them securely.*

CAUTION: Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

20. With the engine mounted on the overhaul stand, remove all of the remaining subassemblies and parts from the cylinder block.

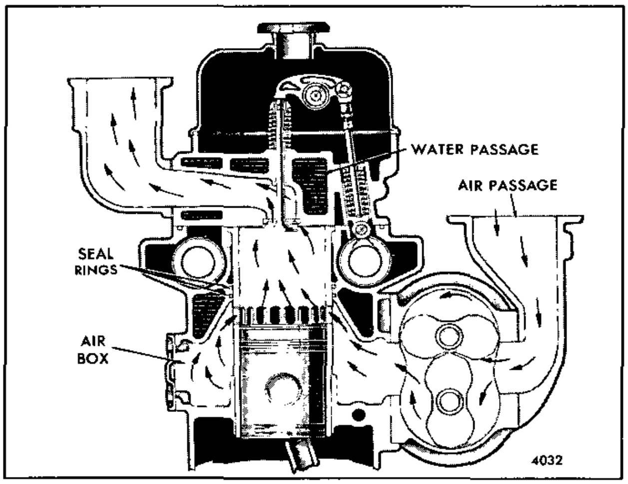


Fig. 3 – Air and Water Passages in In–line Cylinder Block

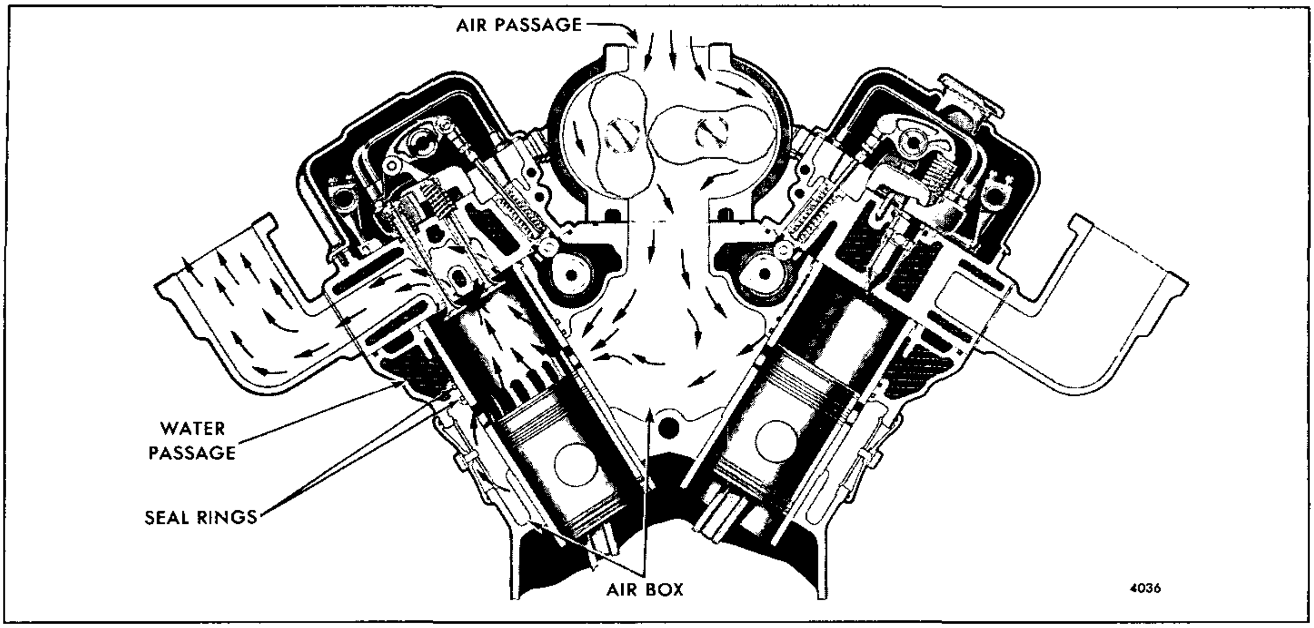


Fig. 4 – Air and Water Passages in 6V–53 Cast Iron Cylinder Block

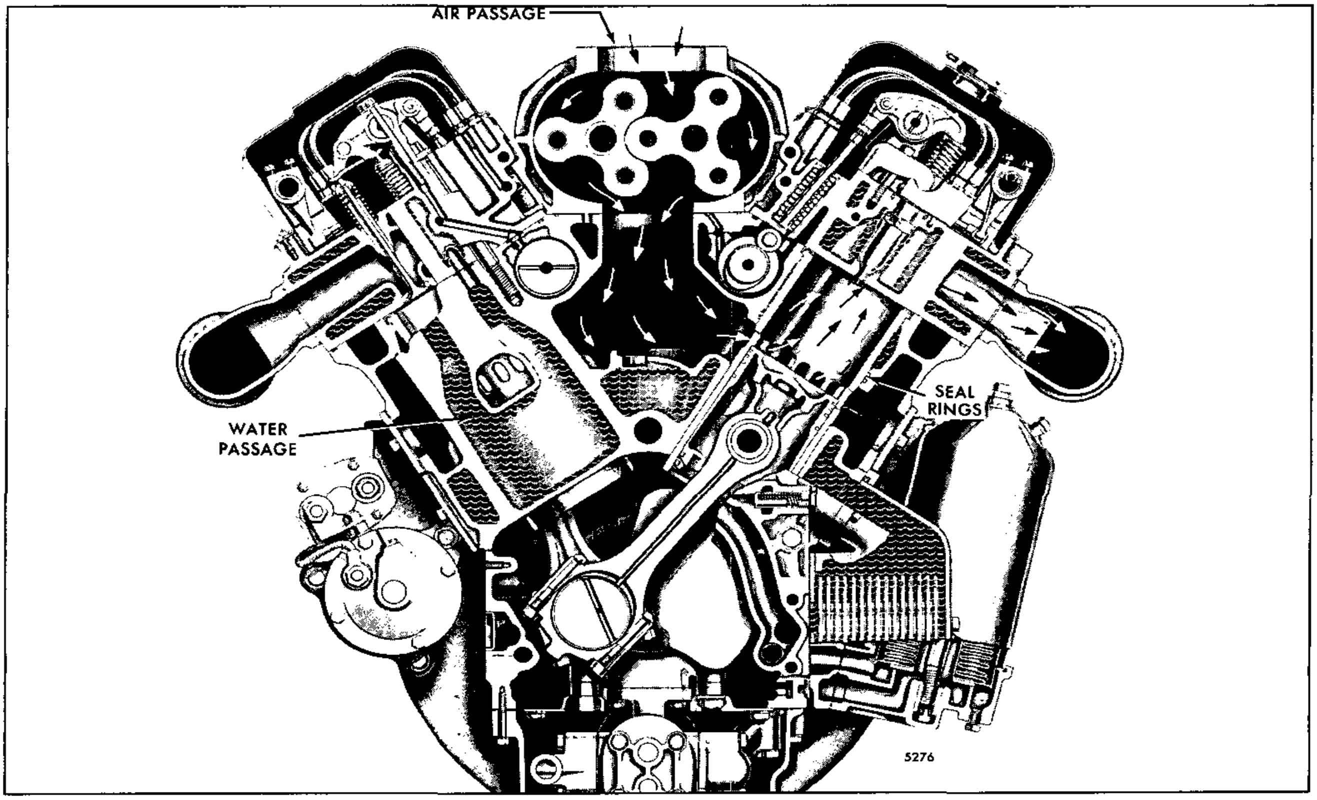


Fig. 5 – Air and Water Passages in 8V–53 Cylinder Block

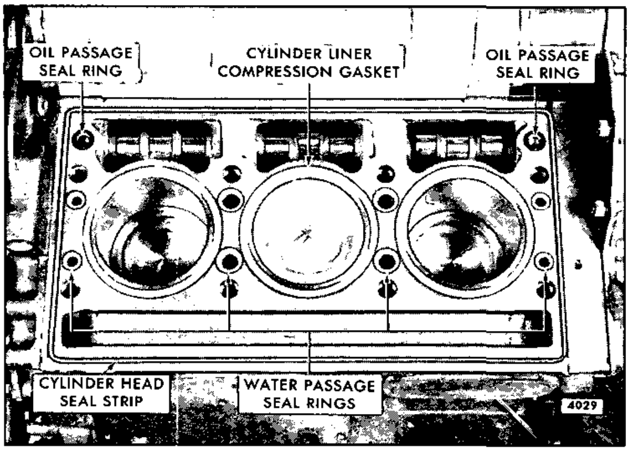


Fig. 6 – Cylinder Head Gaskets and Seals in Place on Cylinder Block

The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various sections of this manual.

After stripping, the cylinder block must be thoroughly cleaned and inspected.

Clean Cylinder Block

1. Remove all of the plugs (except cup plugs) and scrape all old gasket material from the block.
2. Clean the block with live steam.

- **CAUTION: To avoid personal injury (scalding) from the live steam, wear adequate protective clothing (face plate, rubber gloves, apron, and boots) and exercise caution when cleaning.**

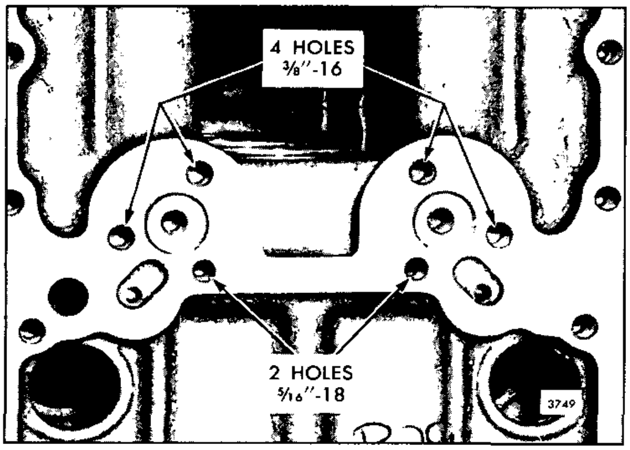


Fig. 7 – Location of the Four 3/8-16 Bolt Holes in Rear of Cylinder Block

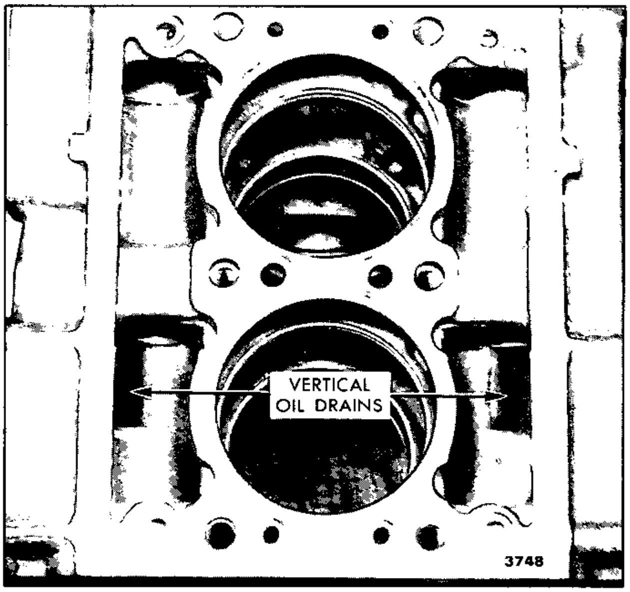


Fig. 8 – Vertical Oil Passages in Top of Cylinder Block

Make sure the oil galleries, air box floor and air box drain openings are thoroughly cleaned. On former engines, jets machined in the camshaft and balance shaft bores (In–line engines) and the camshaft bushing bores (6V–53 engines) permit oil to be sprayed on the cam followers. Make sure they are not plugged. A .020" wire may be used to clean the jets. Jets are not machined in the camshaft and balance shaft bushing bores in the current In–line and 6V–53 cylinder blocks. Oil is directed to the cam followers through small slots incorporated in the camshaft and balance shaft bearings.

3. Dry the block with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Pressure Test Cylinder Block

After the cylinder block has been cleaned, it must be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make a steel plate of 1/2" stock to cover each cylinder bank of the block (Fig. 11). The plate(s) will adequately seal the top surface of the block when used with cylinder liner compression gaskets and water hole seal rings. It will also be necessary to use water hole cover plates and gaskets to seal the water inlet openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line so the water jacket can be pressurized.

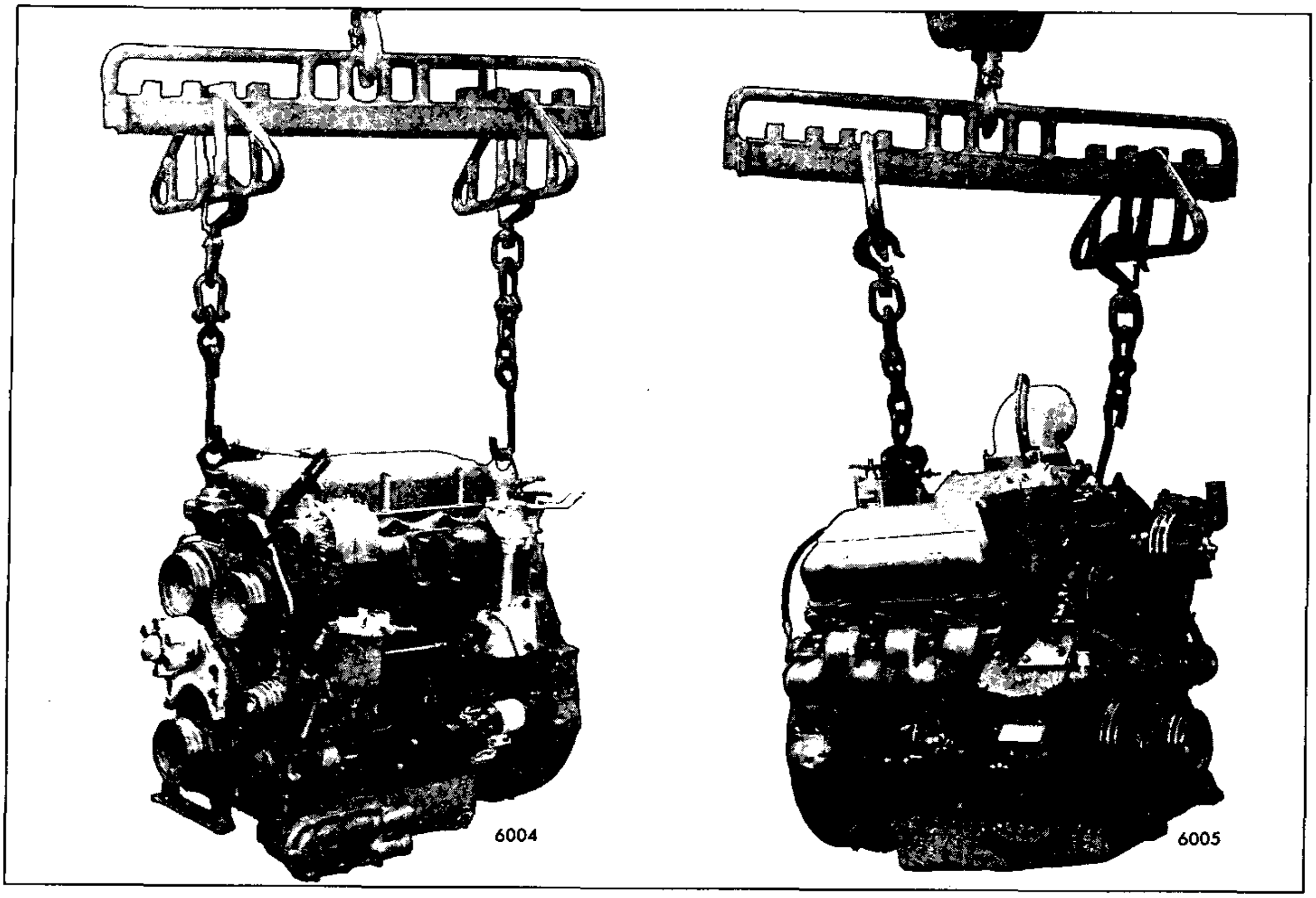


Fig. 9 – Lifting Engine with Spreader and Sling

METHOD "A"

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

1. Make sure the seal ring grooves in the cylinder bores of the block are clean. Then, install new seal rings in the grooves (above the air inlet ports).
2. Apply a light coating of hydrogenated vegetable type shortening or ethylene glycol base antifreeze solution to the seal rings.
3. Slide the cylinder liners into the block, being careful not to roll or damage the seal rings. Install new compression gaskets and water hole seal rings in the counterbores in the top surface of the block.
4. Secure the plate(s) on the top of the block with 5/8"–11 bolts and flat washers.
5. Install the water hole cover plates and gaskets on the sides of the block.

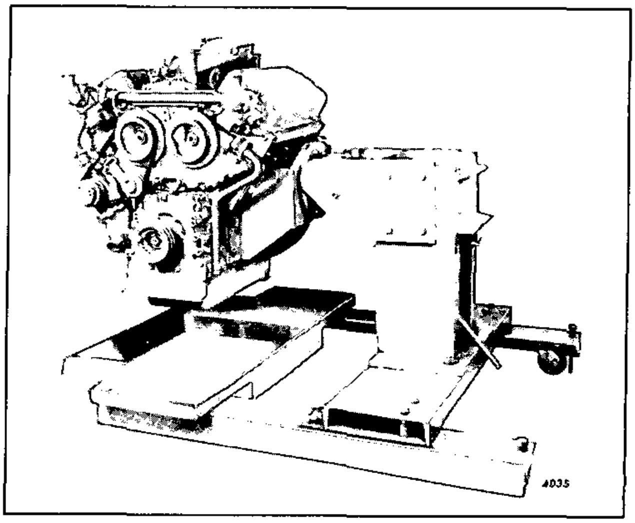


Fig. 10 – Engine Mounted on Overhaul Stand

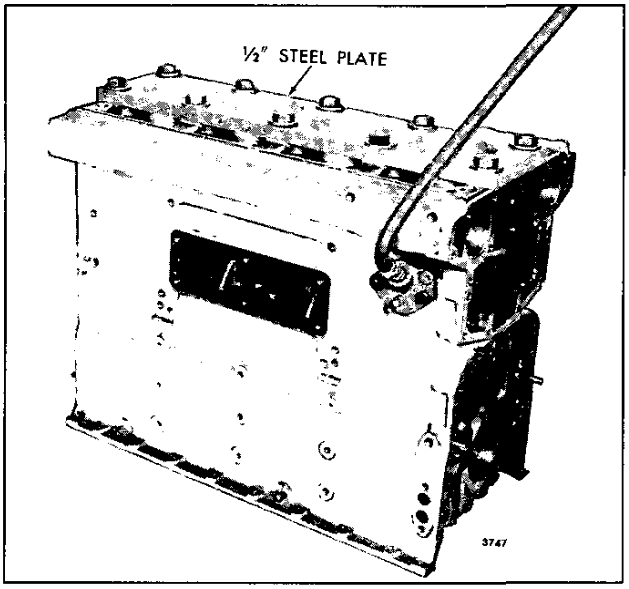


Fig. 11 – Cylinder Block Prepared for Pressure Test

6. Immerse the cylinder block for twenty minutes in a tank of water heated to 180–200°F (82–93°C).

7. Attach an air line to the water hole cover plate and apply 40 psi (276 kPa) air pressure to the water jackets and observe the water in the tank for bubbles which will indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

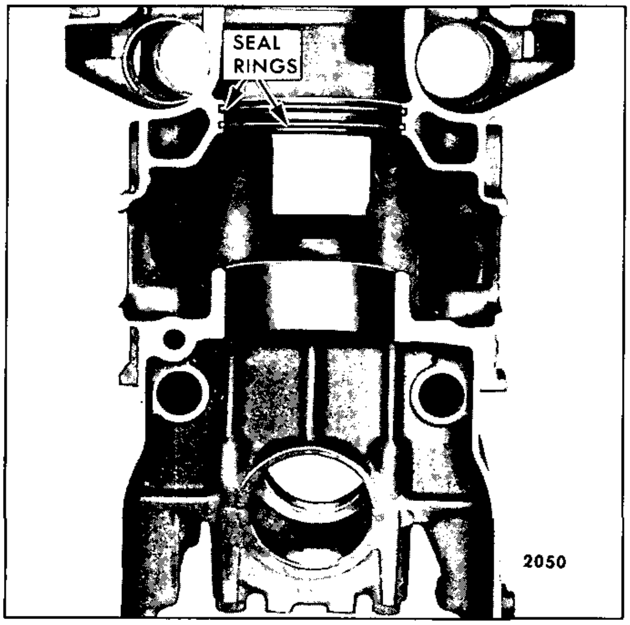


Fig. 12 – Location of Block Bore Seal Ring Groove

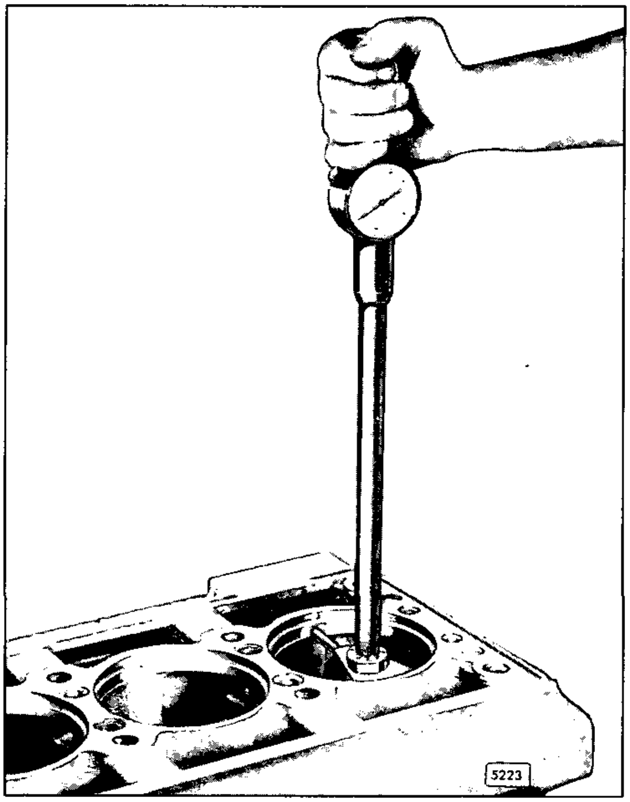


Fig. 13 – Checking Cylinder Block Bore with Tool J 5347-B

8. Remove the block from the water tank. Then, remove the plates, seals, gaskets and liners and blow out all of the passages in the block with compressed air.

9. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

METHOD "B"

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder head(s), blower, oil cooler, air box covers and oil pan.

1. Prepare the block as outlined in Method "A". However, before installing the large sealing plate, fill the water jacket with a mixture of water and one gallon of ethylene glycol base antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

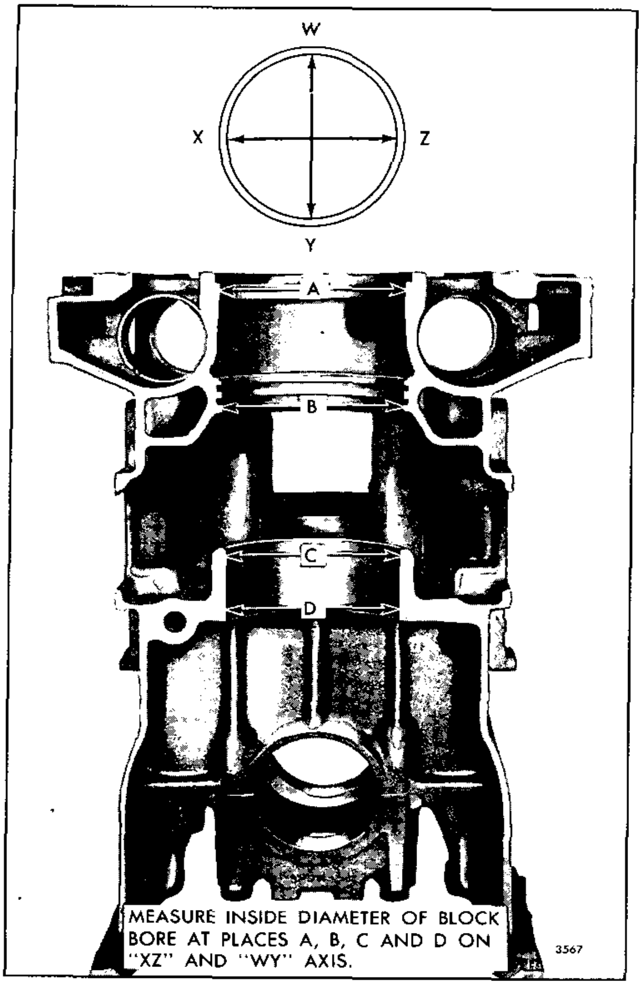


Fig. 14 – Block Bore Measurement Diagram

2. Install the plate(s) and water hole covers as outlined in Method "A".

3. Apply 40 psi (276 kPa) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

4. At the end of this test period, examine the cylinder bores, air box, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

5. After the pressure test is completed, remove the plates and drain the water jacket. Then, remove the liners and seal rings and blow out all of the passages in the block with compressed air.

6. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

1. Check the block bores as follows:

   a. Make sure the seal ring grooves (Fig. 12) are thoroughly clean. Then inspect the grooves and lands for evidence of pitting and erosion. If the grooves are eroded to the extent that sealing is affected, then the block must be replaced.

   b. To determine if an oversize O.D. cylinder liner is required, measure the entire bore of each cylinder with cylinder bore gage J 5347–B (Fig. 13) which has a dial indicator calibrated in .0001" increments. Use dial bore gage setting tool J 23059–01 to preset the cylinder bore gage to zero. Measure each block bore at the positions indicated in Fig. 14, on axis 90° apart. If the diameter does not exceed 4.5235" at position "A", 4.4900" at position "B" (and a sealing problem hasn't occurred), or 4.3595" at position "C" and "D", then the block may be reused. Also, the taper and out of round must not exceed .0015".

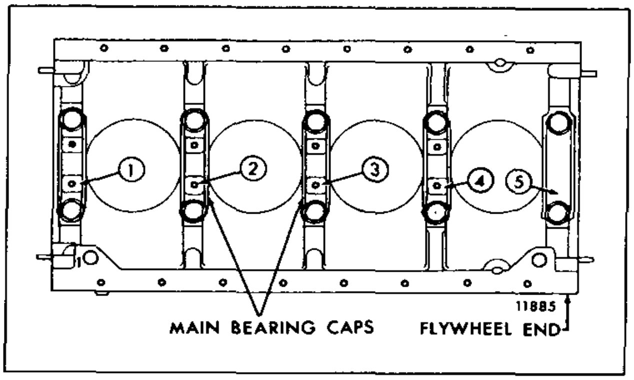


Fig. 15 – Typical Cylinder Block Markings

Portable boring bars are commercially available to bore cylinder blocks oversized. Instructions on their correct use are provided by the manufacturers. When boring the block, measure the block after each cut at the locations shown on Fig. 14 and observe the dimensional limits in Table 1.

OVERSIZE SERVICE CYLINDER LINERS

LINER OVERSIZE	"A" DIAMETER	"B" DIAMETER	"C" & "D" DIAMETERS
.010"	4.5295 / 4.5315	4.4965 / 4.4980	4.3665 / 4.3675
.020"	4.5395 / 4.5415	4.5065 / 4.5080	4.3765 / 4.3775

TABLE 1

Install the oversize liner in the proper bore of the cylinder block, and measure as outlined in Section 1.6.3.

A new liner–to–block seal ring (identified by two non–permanent yellow stripes) has also been released for use with the .020" oversized liner. The standard seal ring has no paint identification and is used only with the standard and .010" oversize O.D. liners.

When oversize liner is installed, stamp the amount of oversize on top of the cylinder bore adjacent to the liner counterbore.

2. Check the top of the block for flatness with an accurate straight edge and a feeler gage. The top surface must not vary more than .003" transversely and not over .005" (2–53 engine), .006" (3–53 or 6V–53 engine) or .007" (4–53 or 8V–53 engine) logitudinally.

3. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth. The depth must be .300" to .302" and must not vary more than .0015" throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001" total indicator reading. There must not be over .001" difference between any two adjacent cylinder counterbores, when measured along the cylinder longitudinal centerline of the cylinder block.

4. Check the main bearing bores as follows:

   a. Check the bore diameters with the main bearing caps in their original positions. Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 15). Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then, install and tighten the bolts to the specified torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 3.251" to 3.252" (In–line engine) or 3.751" to 3.752" (V–type engine). If the bores do not fall within these limits, the cylinder block must be rejected.

   Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Effective with engine serial numbers 6D–27030 and 8D–1155, a new hexagon head bolt and hardened steel washer are being used in place of the former 12–point flange type main bearing cap bolt.

   b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a *finished* replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.

   Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

   c. Main bearing bores are line–bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened to the specified torque. If a main bearing bore is more than .001" out of alignment, the block must be line–bored (see Section 1.0) or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

d. If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line–bored. Install the bearing caps in their original positions (without the bearing cap stabilizers) and tighten the bolts to the specified torque (Section 1.0). Line–bore the block, but do not remove more than .001" stock. After boring, all bores must be within the specified limits of 3.251" to 3.252" (In–line block) or 3.751" to 3.752" (V–type block).

5. Refer to the *Cylinder Block Plugging Charts* – Section 1.0 *Shop Notes* and install the necessary plugs and dowels. Use tool J 34650 to install the new sealant–coated 1/8"–27 pipe plugs.

6. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .680" from the cylinder block face.

The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend .107" to .117" from the surface of the bearing cap.

NOTICE: A stepped dowel pin is available to replace loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. 11 (.1910") or No. 12 (.1890") drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

7. Check all of the machined surfaces and threaded holes in the block. Remove nicks and burrs from the machined surfaces with a file. Clean–up damaged threads in tapped holes with a tap or install helical thread inserts.

NOTICE: Before rebuilding a used cylinder block, check for cracking in the area between the center water transfer holes and the cylinder head–to–block bolt holes (both cam and exhaust sides). If cracking is found, replace the cylinder block.

8. After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip it in a polar type rust preventive such as Valvoline Oil Company's "Tectyl 502–C", or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

Assemble and Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

NOTICE: Before a reconditioned or new service replacement cylinder block is used, thoroughly clean it to remove the rust preventive and blow out the oil galleries with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

1. Mount the block on the overhaul stand.
2. If a new service replacement block is used, stamp the engine serial number and model number on the upper rear corner of the In–line block or the top right–hand corner of the V–type block. Also, stamp the position numbers on the main bearing caps (Fig. 15) and the position of the No. 1 bearing on the oil pan mounting flange of the block.
3. Install all of the required plugs and drain cocks. Use a good grade of non–hardening sealant on the threads of the plugs and drain cocks. If a new service replacement block is used, make sure the top surface is plugged correctly to prevent low oil pressure or the accumulation of abnormal quantities of oil in the cylinder head.
4. Clean and inspect all of the engine parts and subassemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and subassemblies are outlined in the following sections of this manual.
5. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.
6. Install the air box covers and tighten the bolts to 12–15 lb–ft (16–20 N·m) torque. On 6V engines using 1/4" thick air box cover clamp, tighten the bolts to 8–10 lb–ft (11–14 N·m) torque.
7. Complete the engine build–up by installing all remaining accessories, fuel lines, electrical connections, controls etc.
8. Operate the engine on a dynamometer, following the *run–in* procedure outlined in Section 13.2.1.
9. Reinstall the engine in the equipment which it powers.

CYLINDER BLOCK END PLATE

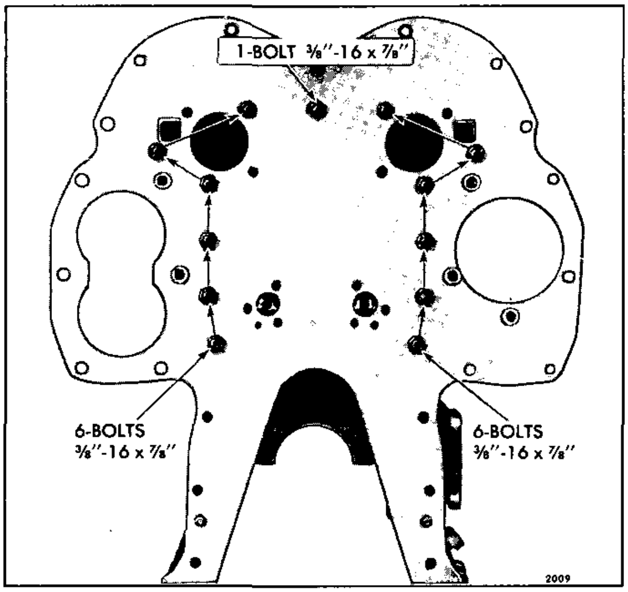


Fig. 1 – Cylinder Block Rear End Plate Mounting (3–53 Engine)

A flat steel plate, bolted to the rear end of the cylinder block, provides a support for the flywheel housing. A gasket is used between the block and the end plate.

Inspection

When the end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and the cylinder block. Clean the end plate as outlined under *Clean Cylinder Block* in Section 1.1.

Inspect both surfaces of the end plate for nicks, dents, scratches or score marks and check it for warpage. Check the plug nuts in the end plate for cracks or damaged threads. If nicks or scratches on the sealing surfaces of the end plate are too deep to be cleaned up, or the plug nuts are damaged, replace the end plate or plug nuts.

When installing a plug nut, support the end plate on a solid flat surface to avoid distorting the plate. Then, press the nut in the end plate until the head on the nut seats on the end plate.

Install End Plate

1. Affix a new gasket to the end of the cylinder block (flywheel end), using a non–hardening gasket cement. Also, apply an even coating of gasket cement to the outer surface of the gasket (the surface next to the end plate).

   On an 8V engine, a cylinder block to end plate (center) gasket is also used. Affix this gasket to the block over the idler gear hub mounting bolt holes.

   Remove the perforated sections from the current end plate gasket before installing the gasket on an engine built prior to 6D–6211.

2. Align the dowel pin holes in the end plate with the dowel pins in the cylinder block (if used). Then, start the end plate over the dowel pins and push it up against the cylinder block.

   When installing the end plate, the heads of the plug nuts at the top of the end plate on the In–line engine, or the two plug nuts in the side of the end plate on the V–type engine, should always face the forward end of the cylinder block.

3. On In–line engines, refer to Figs. 1 or 2 and install the 3/8"–16 x 7/8" bolts with lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

4. Check the backlash between the governor drive gear and the camshaft or balance shaft gear. The backlash should be .0030" to .0050" between new gears and should not exceed .0070" between used gears. If necessary, loosen and readjust the rear end plate to bring the gear lash within specifications.

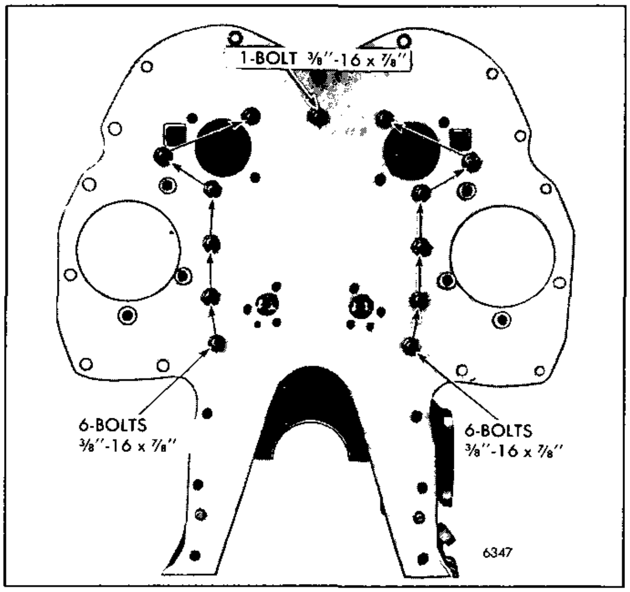


Fig. 2 – Cylinder Block Rear End Plate Mounting (4–53 Engine)

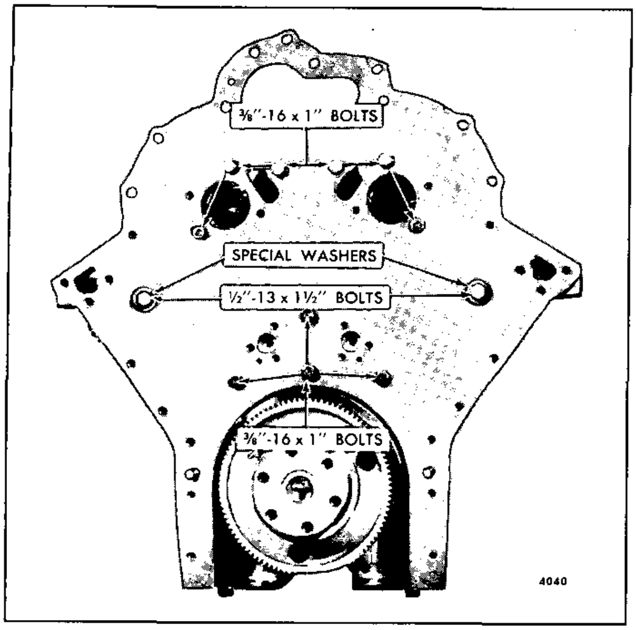


Fig. 3 – Cylinder Block Rear End Plate Mounting (V–Type Engine)

5. On a V–type engine, refer to Fig. 3 for the location and install the 3/8"–16 x 1" bolts with lock washers. Also, install the two special washers and two 1/2"–13 x 1–1/2" bolts as shown when the fuel pump is driven off the camshaft, or one special washer and bolt when the fuel pump is driven by the accessory gear. Tighten the 3/8"–16 bolts to 30–35 lb–ft (41–47 N·m) torque and the 1/2"–13 bolts to 71–75 lb–ft (96–102 N·m) torque.

AIR BOX DRAINS

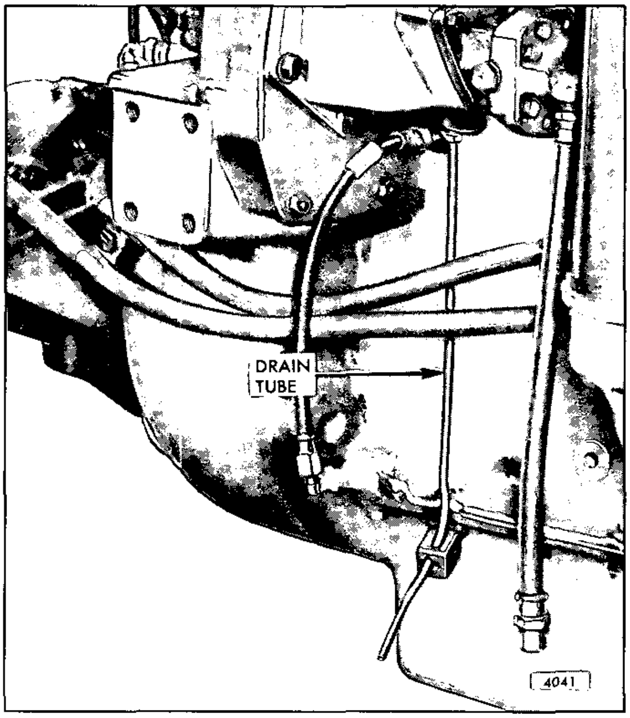


Fig. 1 – Air Box Drain Tube Mounting (In–Line Engines)

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through air box drain tubes mounted on the sides of the cylinder block. The air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

One drain tube is used on an In–line engine (Fig. 1) and two drain tubes are used on the 6V engines (Fig. 2) at the rear end of the cylinder block.

The 8V marine engines, effective with engine 8D–425, have one short and one long drain tube installed at the right front corner and one drain tube at each rear corner of the cylinder block. Effective with engine 8D–2304, marine engines have an oil drain tube at each corner of the cylinder block.

The 8V vehicle engines effective with 8D–425 have one short and one long drain tube installed at the right front corner and one drain tube at each rear corner of the cylinder block (Fig. 3). Industrial engines effective with 8D–435 have a short and a long drain tube installed at the right front corner and the left rear corner, as well as one drain tube at the left front corner and right rear corner; since they may operate inclined in either direction. It is recommended that the additional drain tubes and fittings be installed on engines built prior to 8D–425.

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Section 15.1).

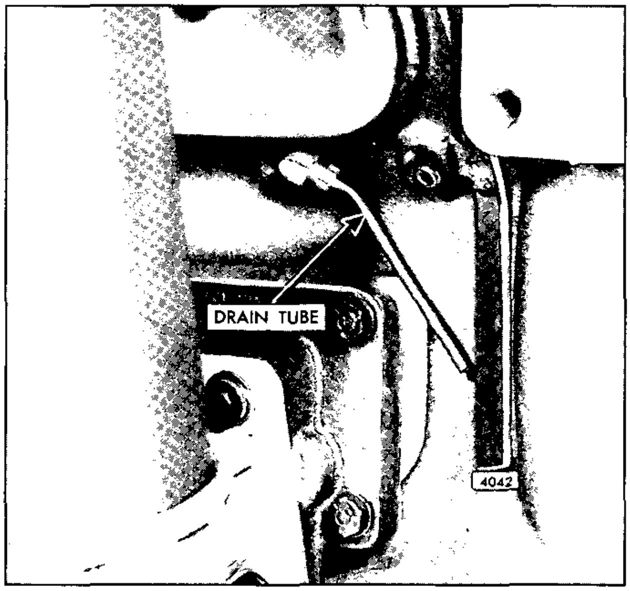


Fig. 2 – Air Box Drain Tube Mounting (6V Engine)

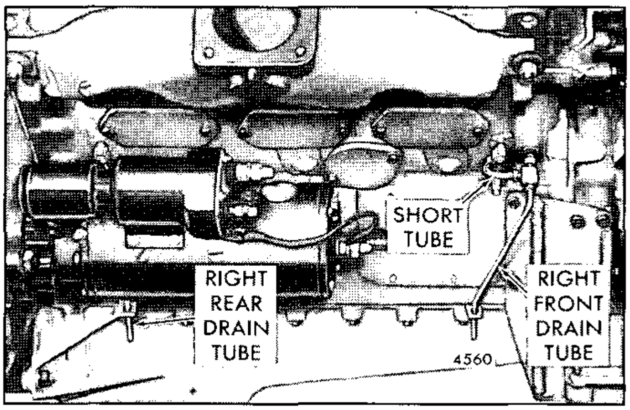


Fig. 3 – Air Box Drain Tube Mounting (8V Engine)

CYLINDER HEAD

The cylinder head is a one–piece casting securely held to the top of the cylinder block by special bolts. (Fig. 1).

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head.

Depending upon the engine application, either two or four exhaust valves are provided for each cylinder.

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of valves under varying conditions of temperature and materially prolong the life of the cylinder head.

To ensure efficient cooling, each fuel injector is inserted into a thin–walled tube which passes through the water space in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a neoprene seal. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles pressed into the water inlet ports in the four–valve cylinder head. The nozzles direct the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which are subjected to the greatest heat. The coolant flow pattern in the two–valve cylinder head is such that nozzles are not required.

The fuel inlet and outlet manifolds are cast as an integral part of the cylinder head. Tapped holes are provided for connection of the fuel lines at various points along each manifold.

To seal compression between the cylinder head and the cylinder liner, separate laminated metal gaskets are provided at each cylinder.

• These may be of one–piece (.059–.063" thick) or two–piece (.070–.085" thick) construction. Both designs are interchangeable and may be mixed in an engine.

Water and oil passages between the cylinder head and cylinder block are sealed with synthetic rubber seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block. When the cylinder head is drawn down, a positive leakproof metal–to–metal contact is assured between the head and the block.

• Fuse Plugs

• Heat–sensitive fuse plugs are installed in the exhaust manifold side of all Series 53 cylinder heads. The insert in these plugs will melt if the "critical" temperature of the head (291°F or 144°C) is exceeded. Current cylinder heads use a 1/8" fuse plug with either a square socket head (production only) or slotted head (service).

• The presence of a melted fuse plug insert is a sure sign that the engine has experienced an overheated condition and that cylinder head damage may have occurred. If a melted fuse plug insert is found in a cylinder head, the cylinder head (both heads on a "V" engine) must be removed and checked for serviceability. All water nozzles and injector hole tubes should be replaced and the proper service fuse plugs installed before cylinder heads are reused.

Cylinder Head Maintenance

Normal engine operating temperature should be maintained (see Section 13.2). The cooling system should be inspected daily and kept full at all times. The cylinder head fire deck will overheat and crack in a short time if the coolant does not cover the fire deck surface. When necessary, add water *slowly* to a hot engine to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

• **CAUTION: Use extreme care when removing a coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.**

Unsuitable water in the cooling system may result in lime and scale formation and prevent proper cooling. The cylinder head should be inspected around the exhaust valve water jackets. This can be done by removing an injector tube. Where inspection discloses such deposits, use a reliable noncorrosive scale remover to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Section 13.3 for *Coolant Specifications*.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and, also, result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to Section 2.1.4.

Overtightened injector clamp bolts may also cause head cracks. Always, use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in cylinder head cracks are:

1. Excess fuel in the cylinders caused by leaking injectors.

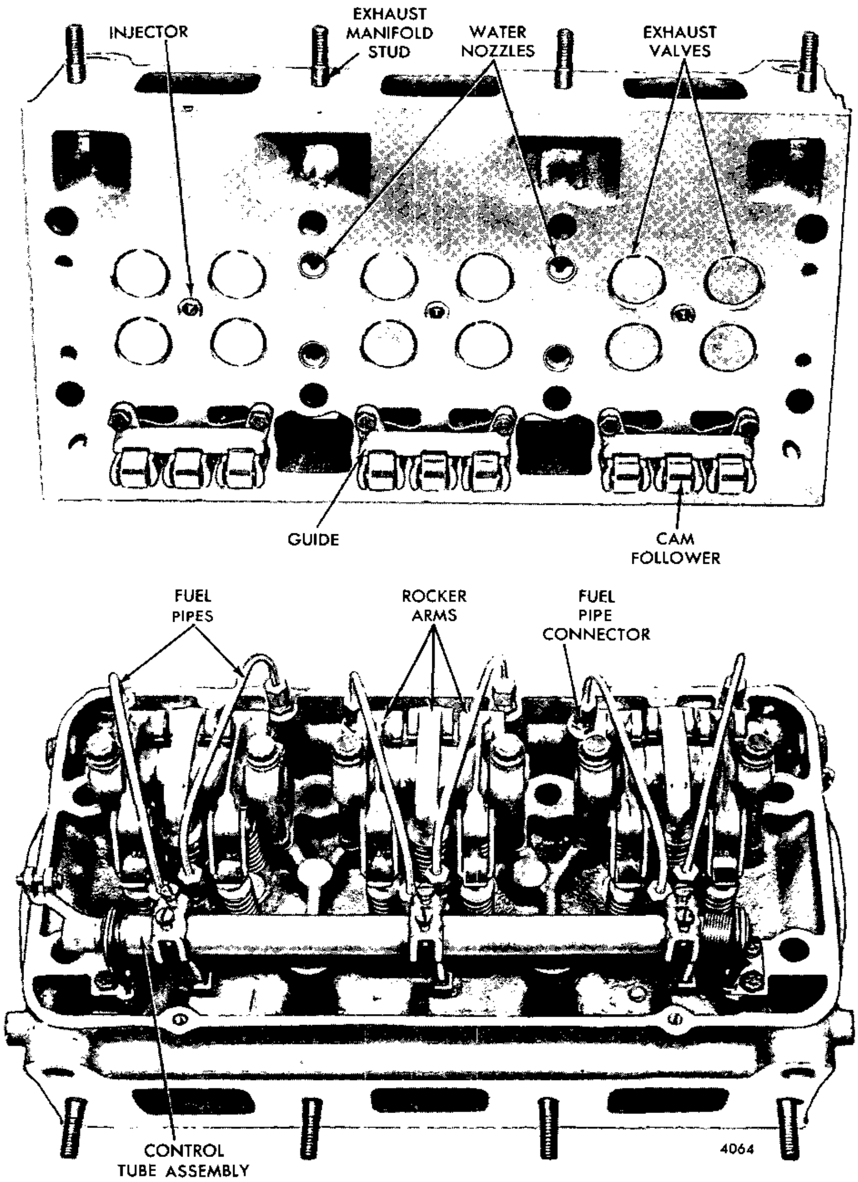


Fig. 1 – Typical Four–Valve Cylinder Head

2. Slipping fan belts can cause overheating by reducing air flow through the radiator.

3. Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.

4. Inoperative radiator cap which will result in loss of coolant.

Remove Cylinder Head

Certain service operations on the engine require removal of the cylinder head:

1. Remove and install pistons.
2. Remove and install cylinder liners.
3. Remove and install exhaust valves.

4. Remove and install exhaust valve guides.
5. Recondition exhaust valves and valve seat inserts.
6. Replace fuel injector tubes.
7. Install new cylinder head gaskets and seals.
8. Remove and install a camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct reinstallation. Then, remove the cylinder head as follows:

1. Allow the engine to cool, then drain the cooling system.
2. Disconnect the exhaust piping at the exhaust manifold.
3. Remove the air cleaners or air silencer.
4. Disconnect the fuel lines at the cylinder head.
5. Remove the thermostat housing and the thermostat as an assembly.
6. Clean and remove the valve rocker cover and governor cover.
7. Disconnect and remove the fuel rod between the governor and the injector control tube lever. Remove the fuel rod cover, if used.

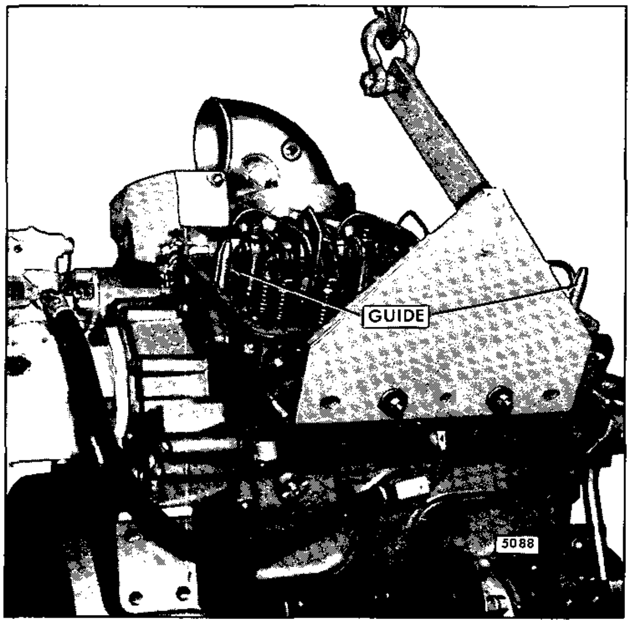


Fig. 2 – Lifting or Installing Cylinder Head with Tool J 22062–01

8. Remove the exhaust manifold.
9. Remove the injector control tube and brackets as an assembly.
10. If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts or for a complete overhaul, remove the fuel pipes and injectors at this time. Refer to Section 2.1 or 2.1.1 for removal of the injectors.
11. Check the torque on the cylinder head bolts before removing the head. Then, remove the bolts and lift the cylinder head from the cylinder block using tool J 22062–01 (Fig. 2). Checking the torque before removing the head bolts and examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

NOTICE: When placing the cylinder head assembly on a bench, protect the cam followers and injector spray tips, if the injectors were not removed, by resting the valve side of the head on 2" thick wood blocks.

12. Remove and discard the cylinder head compression gaskets, oil seals and water seals.
13. After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

Disassemble Cylinder Head

If complete disassembly of the cylinder head is necessary, refer to Sections 1.2.1 and 1.2.2 for removal of the exhaust valve and injector operating mechanism.

Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then, clean the cylinder head in the same manner as outlined for cleaning the cylinder block (Section 1.1).

Clean all of cylinder head components with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

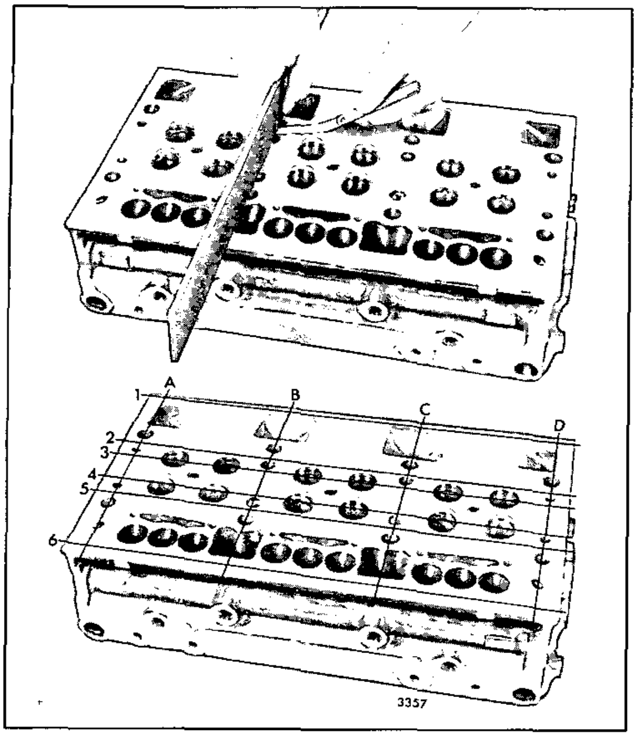


Fig. 3 – Checking Bottom Face of Cylinder Head for Warpage

Inspect Cylinder Head

1. Before a cylinder head can be reused, it must be inspected for cracks. Any one or a combination of the following methods can be used for checking a cylinder head for cracks:

- **NOTICE:** If any method reveals cracks, the cylinder head should be considered unacceptable for reuse. *DDC does not recommend welding Series 53 cylinder heads.*

Magnetic Particle Method: The cylinder head is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which cause the magnetic particles in the powder or solution to gather there, effectively marking the crack. The cylinder head must be demagnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it uses fluorescent magnetic particles which glow under a "Black Light". Very fine cracks, especially on discolored or dark surfaces, that may be missed using the *Magnetic Particle Method* will be disclosed under the "Black Light".

Fluorescent Penetrant Method: A highly fluorescent liquid penetrant is applied to the area in question. Then, the excess penetrant is wiped off the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a "Black Light".

Non-Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agaitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is five to fifteen minutes.

The above four methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

Pressure Test Method: Cylinder head disassembled:

A. Seal off the water holes in the head with steel plates and suitable rubber gaskets secured in place with bolts and washers. Drill and tap one of the cover plates for an air hose connection.

B. Install scrap or dummy injectors to ensure proper seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies — the injector spray tips are not necessary. Tighten the injector clamp bolts to 20–25 lb-ft (27–34 N·m) torque.

C. Apply 40 psi (276 kPa) air pressure to the water jacket. Then, immerse the cylinder head in a tank of water, previously heated to 180–200°F (82–93°C), for about twenty minutes to thoroughly heat the head. Observe the water in the tank for bubbles which indicate a leak or crack. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds and the top or bottom of the cylinder head.

D. Relieve the air pressure and remove the cylinder head from the water tank. Then, remove the plates, gaskets and injectors and dry the head with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

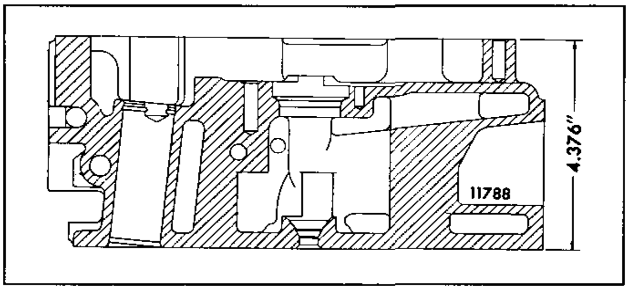


Fig. 4 – Minimum Distance Between Top and Bottom Faces of Cylinder Head

2. Check the bottom (fire deck) of the cylinder head for flatness:

   a. Use a heavy, accurate straight–edge and feeler gages, tool J 3172, to check for transverse warpage at each end and between all cylinders. Also, check for longitudinal warpage in six places (Fig. 3). Refer to Table 1 for maximum allowable warpage.

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
2-53	.004"	.004"
3-53, 6V-53	.005"	.004"
4-53, 8V-53	.006"	.004"

TABLE 1

   b. Use the measurements obtained and the limits given in Table 1 as a guide to determine the advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

   c. If the head is to be refaced, remove the injector tubes prior to machining. Do not remove more metal from the fire deck of any cylinder head below the minimum distance of 4.376" (Fig. 4).

NOTICE: When a cylinder head has been refaced, critical dimensions such as the protrusion of valve seat inserts, exhaust valves, injector tubes and injector spray tips must be checked and corrected. The push rods must also be adjusted to prevent the exhaust valves from striking the pistons after the cylinder head is reinstalled in the engine.

3. Install new injector tubes (Section 2.1.4) if the old tubes leaked or the cylinder head was refaced.

4. Inspect the exhaust valve seat inserts and valve guides (refer to Section 1.2.2).

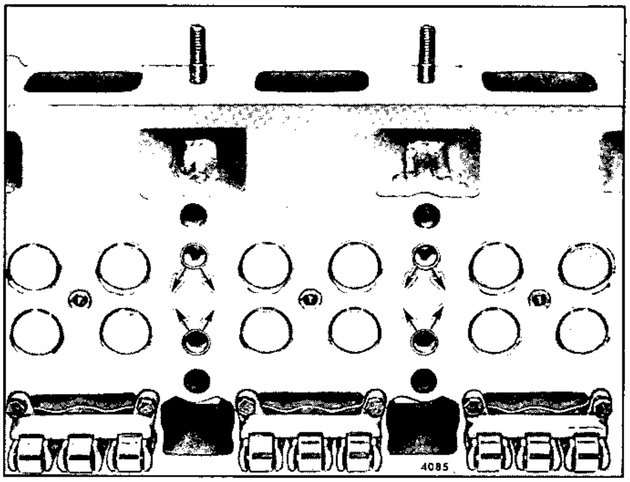


Fig. 5 – Correct Installation of Water Nozzles in Four–Valve Cylinder Head

5. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the followers and bores to determine the cam follower–to–bore clearances. The clearance must not exceed .006" with used parts (refer to Section 1.0 – Specifications). If the bores are excessively scored or worn, replace the cylinder head.

6. Check the water hole nozzles (four–valve head only) to be sure they are not loose. If necessary, replace the nozzles as follows:

   a. Remove the old nozzles.

   b. Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes may be cleaned up with a 5/8" drill. Break the edges of the holes slightly.

   c. Press the nozzles in place with the nozzle openings positioned as shown in Fig. 5. Press the nozzles flush to .0312" recessed below the surface of the cylinder head.

   d. Check to make sure the nozzles fit tight. If necessary, use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder.

7. Replace broken or damaged exhaust manifold studs. Apply sealant to the threads and drive new studs to 25–40 lb–ft (34–54 N·m) torque (1.40"–1.50" height).

8. Inspect all other components removed from the cylinder head.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventive compound is to immerse the head in mineral spirits based solvent or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. A suitable brush for cleaning the various passages in the head can be made by attaching a 1/8" diameter brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes and the necessary plugs.

Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

1. Coat the threads of the plugs with Locite Pipe Sealant with Teflon, then install the necessary plugs and tighten them to the specified torque (Section 1.0). Drive headless plugs flush to .0625" below the surface of the cylinder head. Use tool J 34650 to install the new sealant-coated 1/8"-27 pipe plugs.

2. After the following parts are cleaned and inspected, and replaced, if necessary, reinstall them in the old cylinder head or transfer them to the new head:

   a. Exhaust valves, valve seat inserts and springs (Section 1.2.2).

   b. Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts (Section 1.2.1).

   • c. Visually inspect the fuel connectors for cracks, nicks, and defective threads. Place new washers on the fuel connectors and install them in the head. Tighten connectors used with flared end fuel pipes to 20-28 lb-ft (27-38 N·m) torque. Tighten connectors used with O-ring sealed fuel pipes to 37 lb-ft (50 N·m) torque.

   d. The fuel injectors, fuel pipes and injector control tube assembly can be installed at this time or after the cylinder head is installed on the engine.

Pre-Installation Inspection

Make the following inspections just prior to installing the cylinder head whether the head was removed to service only the head or to facilitate other repairs to the engine.

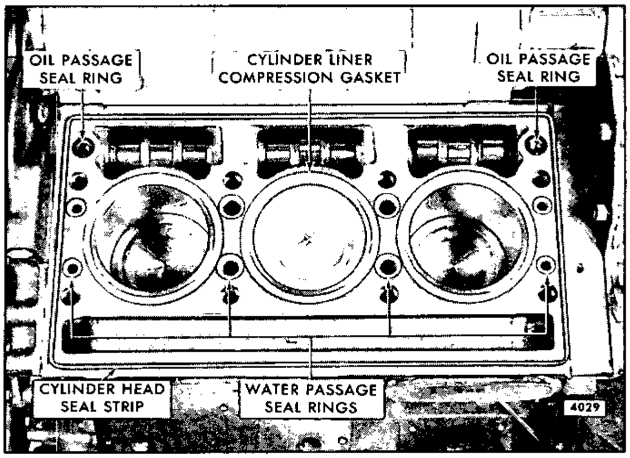


Fig. 6 – Cylinder Head Gaskets and Seals in Place on Cylinder Block

1. Check the cylinder liner flange heights with relationship to the cylinder block (Section 1.6.3).

2. Make sure the piston crowns are clean and free of foreign material.

3. Make sure that each push rod is threaded into its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during engine tune-up.

4. Check the cylinder block and cylinder head gasket surfaces, counterbores and seal grooves to be sure they are clean and free of foreign material. Also, check to ensure that there are no burrs or sharp edges in the counterbores.

5. Inspect the cylinder head bolt holes in the block for accumulation of water, oil or any foreign material. Clean the bolt holes thoroughly and check for damaged threads.

Install Cylinder Head

1. Refer to Fig. 6 and install the water and oil seal rings and compression gaskets as follows:

   • a. Place a new compression gasket on top of each cylinder liner. *Never* install used gaskets or seals.

   b. Place new seal rings in the counterbores of the water and oil holes in the cylinder block. Silicone-composition water hole seals can be damaged if they move out of position in the

 May, 1990

cylinder block counterbore during engine rebuild. In turn, damaged seals can allow engine coolant to contaminate lube oil and cause serious engine damage. To prevent this, a spray adhesive may be used to hold seals in place if the following precautions are taken:

1). Attach a mask or template to the cylinder block fire deck to minimize overspray.

2). Using a high–tack, spray type adhesive suitable for synthetic rubber seals (*3M Company Super–Tack Gasket Adhesive #8082,* or equivalent), spray a *light,* uniform coating of adhesive into the seal counterbores. Keep the adhesive off of adjacent block surfaces and wipe off any that gets on the fire deck or liner bores.

3). Allow the adhesive to dry to a high–tack consistency (stickiness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive.

NOTICE: Do not apply adhesive directly to the seal. The adhesive will coat the I.D. of the seal and the spray propellant may cause the seal to swell temporarily.

c. Install a new oil seal in the groove at the perimeter of the cylinder block. The seal must lay flat in the groove and *must not* be twisted or stretched when installed. Installing the seal strip in the groove with the colored stripe facing away from the cylinder bores can improve its sealing capibilities.

3M Company Super–Tack Gasket adhesive #8082 or equivalent may also be used to hold the peripheral head–to–block oil seals in place during engine rebuild.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, use guide studs J 9665. Install the studs in the end cylinder block bolt holes on the camshaft side of the cylinder head (Fig. 2).

3. Attach lifting tool J 22062–01 to the cylinder head and lift the head into position above the cylinder block.

4. Make a final visual check of the compression gaskets and seals to ensure that they are in place before the cylinder head is lowered. *This is a very important check.* Gaskets and seals which are not seated properly will cause leaks and "blowby" and result in poor engine performance and damage to the engine.

5. Wipe the bottom of the cylinder head clean. Then, lower the head until it is about 1/2″ from the surface of the cylinder block.

6. Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of each cylinder head attaching bolt. Then, install the bolts finger tight. On the In–line engines equipped with both six and twelve point bolts, the twelve point bolts must be installed on the camshaft side of the head to eliminate possible interference between the governor control link and the cylinder head bolt. Continue to tighten the bolts as the head is lowered on the cylinder block. Cylinder head bolts are expecially designed for this purpose and must not be replaced by ordinary bolts.

7. After the head is in place, remove the guide studs and chain hoist and install the remaining bolts, running all bolts down snug tight with a speed handle (15–20 lb–ft or 20–27 N·m torque). However, *before* tightening the bolts, loosen the lifter bracket–to–cylinder head attaching bolts, otherwise, the head may be prevented from seating properly on the cylinder block. A similar condition could exist if the exhaust manifold is attached to the cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block. On some engine models, these bosses serve as a rest for the exhaust manifold after the cylinder head has been installed on the cylinder block.

8. Tighten the bolts to 170–180 lb–ft (231–244 N·m) torque in 50 lb–ft (68 N·m) increments with a torque wrench, in the sequence shown in Fig. 7. Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tightening of the remaining bolts. Apply a steady pressure for two or three seconds at the prescribed torque to allow the bolts to turn while the gaskets yield to their final designed thickness. *Begin on the cam follower side of the head* to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification, but do not exceed the limit or the bolts may stretch beyond their elastic limits.

NOTICE: Attempting to tighten the bolts in one step may result in trouble and consequent loss of time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

NOTICE: Tightening the cylinder head bolts will not correct a leaking compression gasket or seal. The head must be removed and the damaged gasket or seal replaced.

9. Cover the oil drain holes in the cylinder head to prevent foreign objects from failing into the holes.

10. If the fuel injectors were not previously installed, refer to Section 2.1 or 2.1.1 and install them at this time.

11. Tighten the rocker arm bracket bolts to 50–55 lb–ft (68–75 N·m) torque.

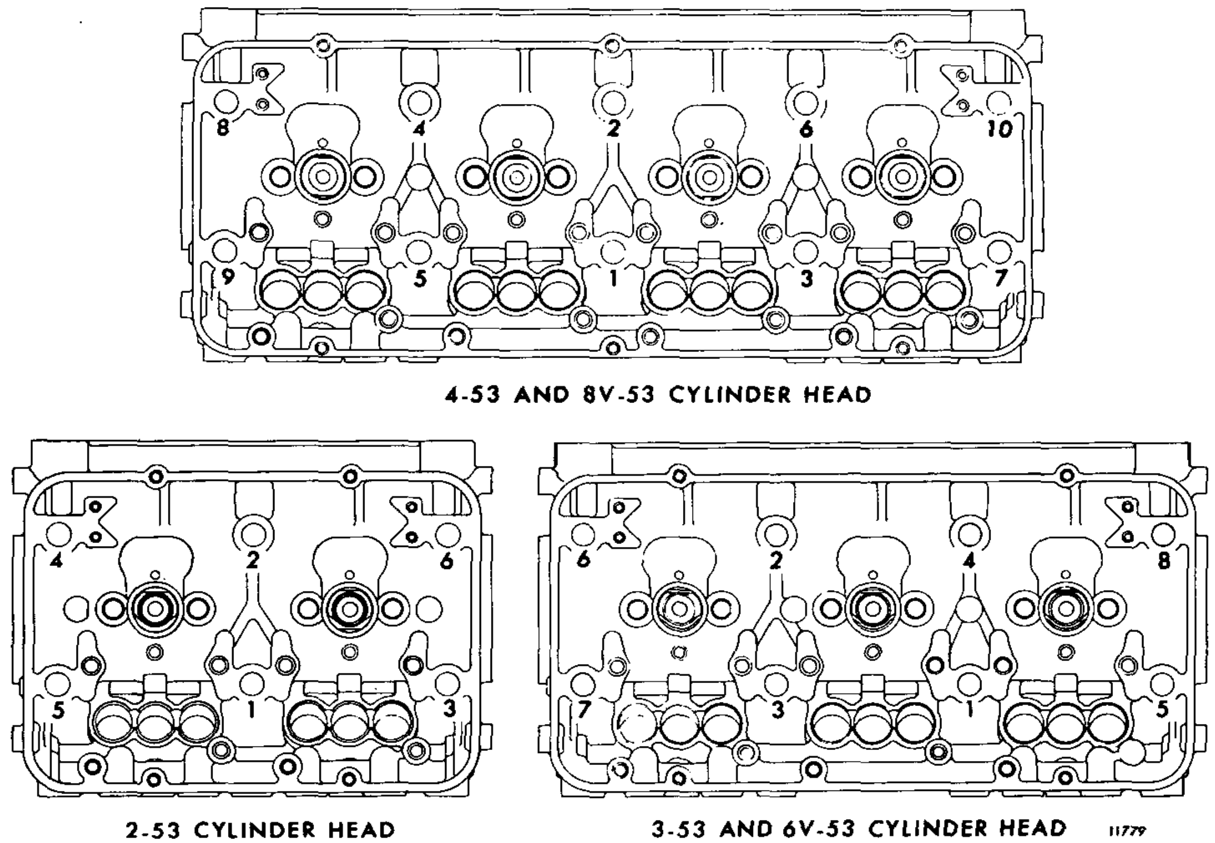


Fig. 7 – Cylinder Head Bolt Tightening Sequence

NOTICE: The exhaust valves on a four–valve head may be damaged if the valve bridges are not resting on the ends of the exhaust valves when tightening the rocker arm bracket bolts (refer to Section 1.2.1 under *Install Rocker Arm and Rocker Arm Shaft*). Therefore, note the position of the valve bridges before, during and after tightening the bolts.

● 12. Install fuel pipes.

A. *Flared End Fuel Pipes.* Align the fuel pipes and connect them to the injectors and the fuel connectors.

NOTICE: DDC recommends that the original *fuel pipes not be reused. New flared end fuel* pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque *specifications. Fuel leakage from damaged or* improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

To help insure more consistent fastening, tighten fuel pipe nuts on fuel pipes to the single torque values shown on the chart.

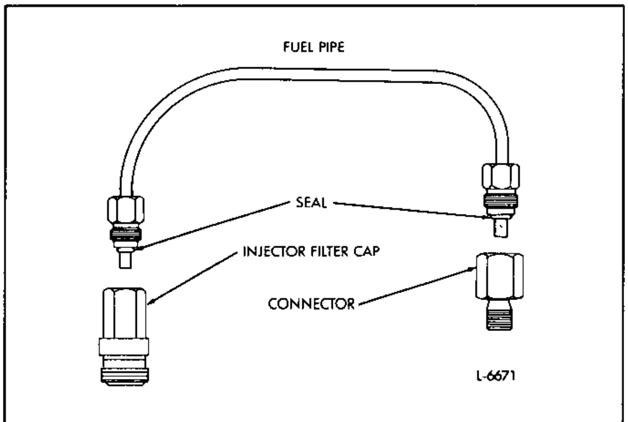
NOTICE: Because of their low friction *surface, Endurion® –coated nuts on fuel pipes* must be tightened to 130–***lb–in*** (14.69 N·m torque, instead of the 160 ***lb–in*** (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening fuel nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

Jacobs brake fuel pipes and those used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

*Not serviced. Available from Jacobs Manufacturing Company.

NOTICE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Fuel Jumper Line Maintenance and Pressurize Fuel System – Check for Leaks* in Section 2.0).



• Fig. 8 – O–Ring Sealed Fuel Pipe, Connector, Injector Filter Cap

B. *O–Ring Sealed Fuel Pipes*. Inspect fuel pipes and connectors (Fig. 8) carefully. Fuel pipes may be reused if they are not twisted, bent, distorted or otherwise damaged.

O–ring design fuel pipes are not interchangeable with flared tube design fuel pipes on a part–for–part basis. O–ring design fuel pipe connectors and injector filter caps have a 1/2" – 20 female thread to accept the 1/2" – 20 male thread on the fuel pipe nuts. These parts must be used together to insure interchangeability.

NOTICE: To avoid fuel leakage, always use new O–ring seals when replacing the fuel pipes on an engine. Do not reuse seals.

Remove the injector shipping caps. Align the fuel pipes and connect them to the injector filter caps and the cylinder head connectors. Using "clicker" type torque wrench J 24405 (calibrated in inch–pounds), tighten the O–ring sealed fuel pipe nuts to 143 ***lb–in*** (16.16 N·m) torque. Oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks* in Section 2.0).

13. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the control tube, be sure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10–12 lb–ft (14–16 N·m) torque.

14. After tightening the bolts, revolve the injector control tube to be sure the return spring pulls the injector racks out (no–fuel position) after they have been moved all the way in (full–fuel position). Since the injector control tube is mounted in self–aligning bearings, tapping the tube lightly will remove any bind that may exist. The injector racks *must* return to the no–fuel position freely by aid of the return spring only. *Do not bend the spring.* If necessary, replace the spring.

15. Install the fuel rod and the fuel rod cover (if used).

16. Remove the covers from the drain holes in the cylinder head.

17. Install the exhaust manifold and connect the exhaust piping.

18. Install the thermostat housing and thermostat.

19. Install the air cleaner or air silencer.

20. Connect the fuel lines.

21. Install any other equipment that was previously removed.

22. Refer to Section 13.1 under *Preparation for Starting Engine First Time* and fill the cooling system and lubrication system.

23. Before starting the engine, perform an engine tune–up as outlined in Section 14.

VALVE AND INJECTOR OPERATING MECHANISM

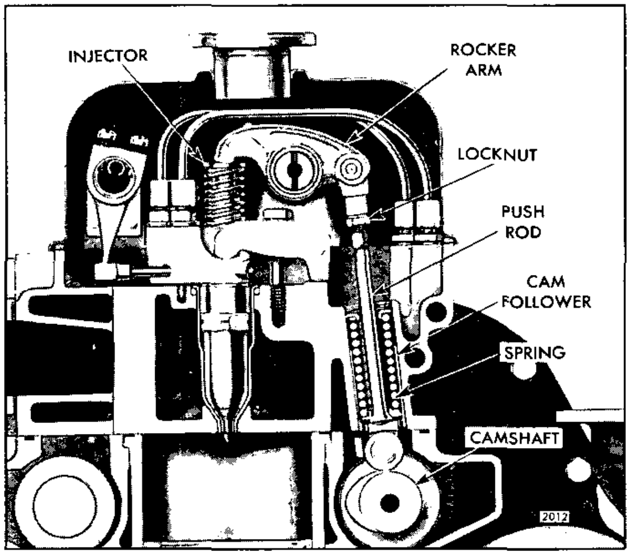


Fig. 1 – Valve and Injector Operating Mechanism

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by a camshaft through cam followers and short push rods extending through the cylinder head (Fig. 1).

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes.

A coil spring, inside of each cam follower, maintains a pre–determined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms.

Overflow oil from the rocker arms lubricates the exhaust valves and cam followers. The oil then drains from the top deck of the cylinder head through oil holes in the cam followers, into the camshaft pockets in the cylinder block and back to the oil pan.

The cam follower rollers are lubricated with oil from the cam followers, oil picked up by the camshaft lobes and by oil emitted under pressure from grooves in the camshaft bushing bores in the cylinder block.

Service

Some service operations may be performed on the valve and injector operating mechanism without removing the cylinder head:

1. Adjust valve clearance.
2. Replace a valve spring.
3. Replace a rocker arm.
4. Replace a rocker arm shaft or bracket.
5. Replace a fuel injector.

It is also possible to replace a push rod, push rod spring, the spring seats or a cam follower without removing the cylinder head. However, these parts are more easily changed from the lower side when the cylinder head is off the engine. Both methods are covered in this section.

To replace the exhaust valves and valve seat inserts, the cylinder head must be removed (refer to Section 1.2).

Remove Rocker Arms and Shaft

1. Clean and remove the valve rocker cover. Discard the gasket(s).
2. Remove the fuel pipes from the injector and the fuel connectors.

   NOTICE: Immediately after, removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

3. Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

4. Remove the two bolts which secure the rocker arm shaft brackets to the cylinder head. Also, remove the valve rocker cover hold–down bracket on engines equipped with a cast aluminum rocker cover. Then, remove the brackets and shaft.

   NOTICE: When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. *Do not* force the rocker arms all the way back with the shaft in place as this may impose a load that could bend the push rods.

5. Loosen the locknuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods.

If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be reinstalled in their *original* positions.

Inspection

Wash the rocker arms, shaft, brackets and bolts with clean fuel oil. Use a small wire to clean out the drilled oil passages in the rocker arms and rocker shaft bolts. Dry the parts with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the rocker arm shaft, injector rocker arm bushings or valve rocker arm bores for wear. A maximum shaft–to–bushing (or bore) clearance of .004" is allowable with used parts (refer to Section 1.0). Service replacement injector rocker arm bushings must be reamed to size after installation.

- Inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces). If worn, the surface may be refaced up to a maximum of .010" and requalified with master rocker arm radius gage J 28599. Proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also, inspect the valve bridges (four–valve head) for wear.

Remove Cam Follower and Push Rod (Cylinder Head on Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats and cam follower from the top of the cylinder head, proceed as follows:

1. Remove the rocker arm shaft and brackets as outlined under *Remove Rocker Arms and Shaft.*
2. Loosen the locknut and unscrew the rocker arm from the push rod to be removed. Remove the locknut.
3. Install remover J 3092–01, a flat washer and the locknut on the push rod, with the lower end of the tool resting on the upper spring seat.
4. Thread the nut down to compress the spring.
5. Remove the spring seat retainer from the groove in the cylinder head (Fig. 2).
6. Unscrew the locknut to release the spring. Then, remove the nut, flat washer and tool from the push rod.
7. Pull the push rod, spring, spring seats and cam follower out of the cylinder head.

Remove Cam Follower and Push Rod (Cylinder Head Removed)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

1. Rest the cylinder head on its side and remove the cam follower guide (Fig. 3).

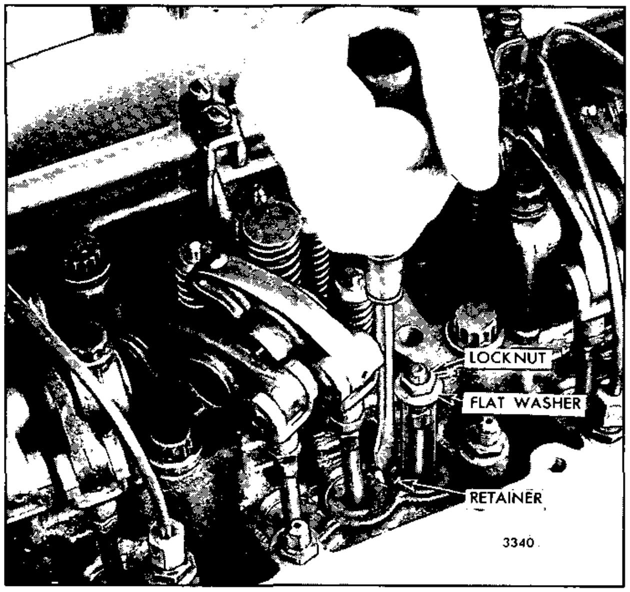


Fig. 2 – Removing Push Rod from Upper Side of Cylinder Head Using Tool J 3092-01

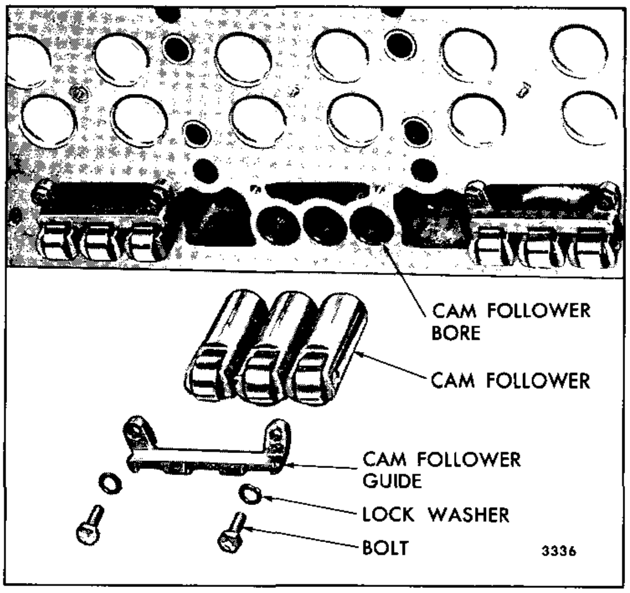


Fig. 3 – Cam Followers and Guide

2. Pull the cam follower out of the cylinder head.

3. Remove the fuel pipes from the injector and the fuel connectors.

NOTICE: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

4. Loosen the push rod locknut and unscrew the push rod from the rocker arm clevis.

5. Pull the push rod and spring assembly from the bottom of the cylinder head.

6. Remove the push rod locknut, spring and spring seats from the push rod.

If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start–up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs and spring seats may be washed with clean fuel oil and dried with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 4. Cam followers stamped with the letter "S" on the pin, roller and follower body are equipped with an oversized pin and roller. The same clearances apply to either a standard or oversize cam follower assembly.

Examine the camshaft lobes for scoring, pitting or flat spots. Replace the camshaft, if necessary.

Measure the cam follower bores in the cylinder head with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower–to–bore clearances (refer to Section 1.0 for Specifications).

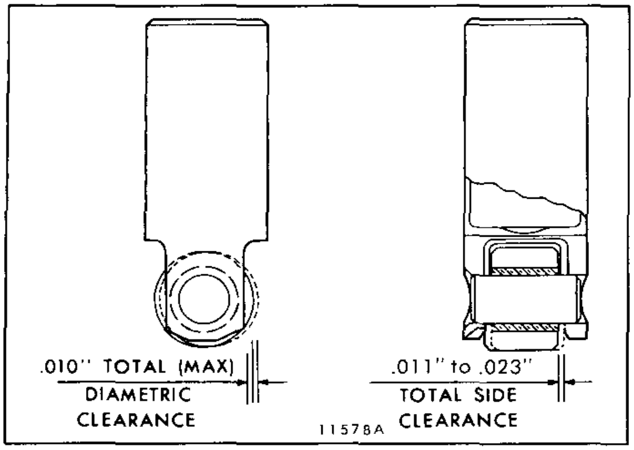


Fig. 4 – Cam Roller Clearances

If the push rod breaks or is damaged, the rocker arm should be suspect. Any wear or excessive movement in the rocker arm or clevis can put a side load on the push rod, resulting in fracture or damage. Before replacing the push rod, inspect the rocker arm for signs of wear or cracking. If wear or excessive movement of the rocker arm or clevis is noted, replace the rocker arm.

Inspect the push rods and spring seats for wear.

Examine the cam follower springs for wear or damage and check the spring load.

The current push rod spring (Fig. 5) is made from .1920" diameter wire and was first used only in the injector cam follower position. The former push rod spring was made from .1770" diameter wire.

Use spring tester J 22738–02 to check the spring load (Fig. 6). Replace the current type spring when a load of less than 250 pounds will compress it to a length of 2.1406". Replace the former type spring when a load of less than 172 pounds will compress it to a length of 2.1250".

It is recommended that if one former type push rod spring requires replacement, all of the former type springs in either the injector or valve cam follower positions be replaced by the current type spring. A new design upper spring seat is required with the use of the current push rod spring.

Replace Cam Roller and Pin

Do not attempt to bore out the legs of a standard cam follower for an oversized pin.

To replace a cam roller and pin, proceed as follows:

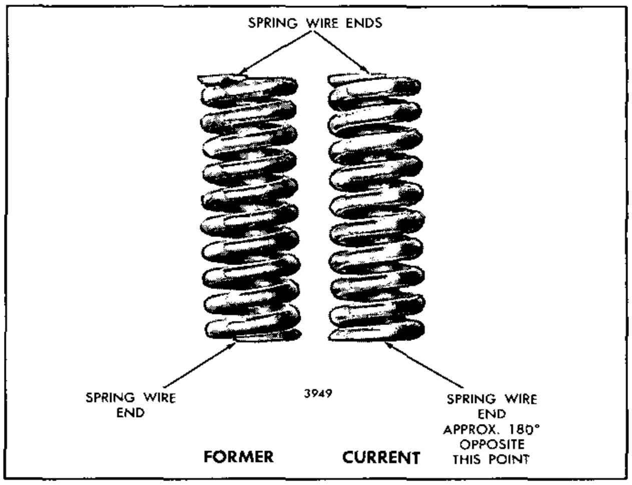


Fig. 5 – Spring Identification

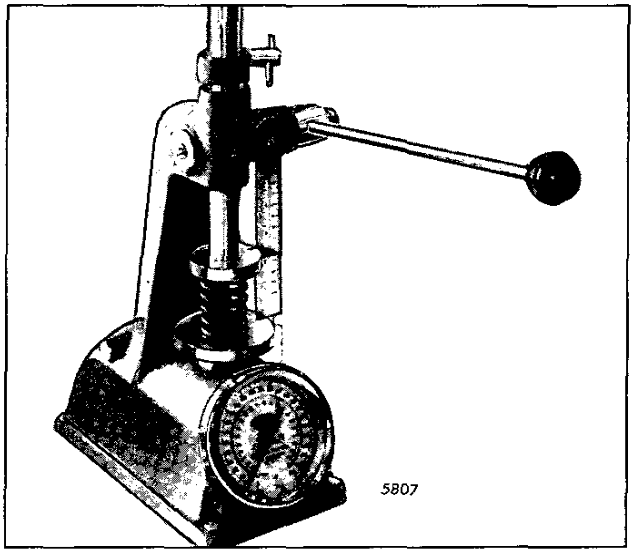


Fig. 6 – Testing Cam Follower Spring Using Tool J 22738–02

DISASSEMBLE CAM FOLLOWER

1. Pull the adjustable sliding support out against its stop (Fig. 7).

2. Place the cam follower with follower pin resting on the spring–loaded guide pin in the fixture. Push the follower down until the lower leg engages the slot in the support plate. This supports the roller which in turn supports the upper follower leg. Then, push the follower in until contact is made with the roller stop screw. This should put the roller pin in alignment with the pressing ram.

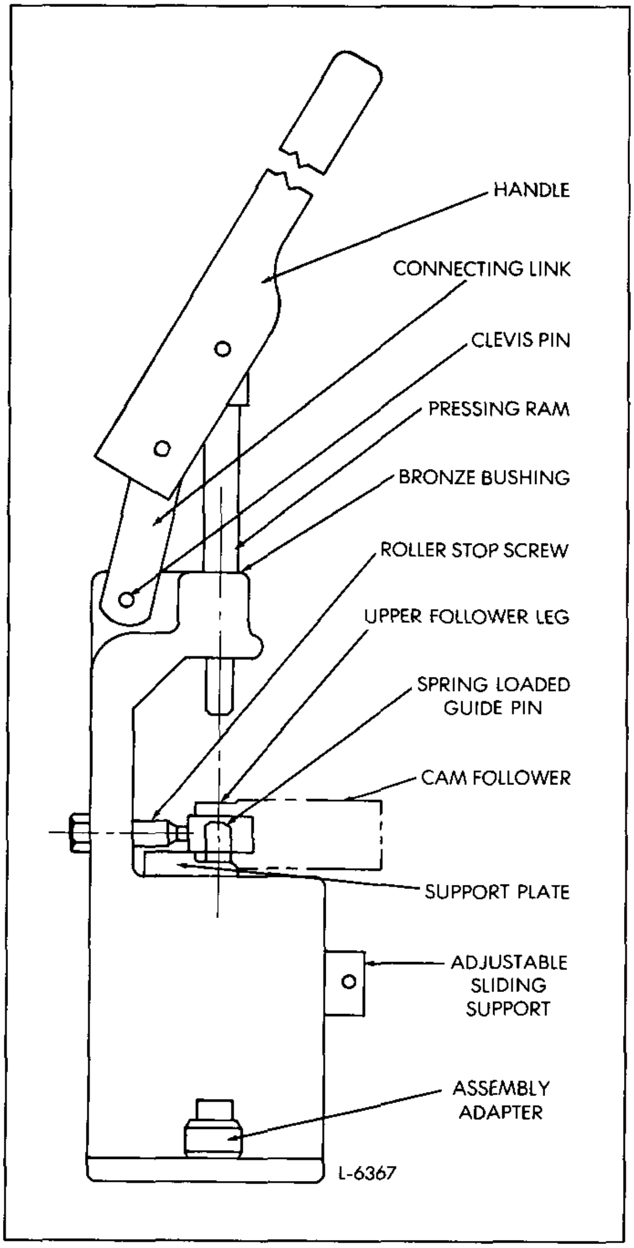


Fig. 7 – Removing or Installing Cam Follower Roller Using Tool J 33421

3. Lower the handle to put pressure on the roller pin.

4. Push the adjustable sliding support in until resistance is felt. This causes the lower follower leg to be supported.

5. Press the pin from the cam follower.

ASSEMBLE CAM FOLLOWER

NOTICE: Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* After washing the parts, lubricate the roller and pin with Cindol 1705.

1. To install a new pin, pull the adjustable sliding support out and position the cam follower in the fixture (roller in place) as in Step 2 above.

   - When assembling the cam follower with flats on the outside of the legs, push adaptor J 33421-3 onto the pressing ram to the limit depth of the press to the correct dimension. When pressing the pin into the follower with rounded legs, use adaptor J 33421-22. Both adaptors have a spring-loaded plunger in the set screw that does not normally require any adjustment.

2. Align the pin over the follower leg, lower handle and place pressure on the pin.

3. To support the lower follower leg, push the adjustable sliding support in until resistance is felt.

4. Press the pin into place.

5. Remove the cam follower from the fixture and check the side clearance (Fig. 4). The clearance must be .011" to .023".

• Test Roller Pin

After rebuilding the cam follower, test the roller pin using Load Test Cell J 33421-26. The pin **must** sustain an axial force of 300 pounds without pushing out. Install the load cell on the pressing ram of the service fixture and proceed as follows:

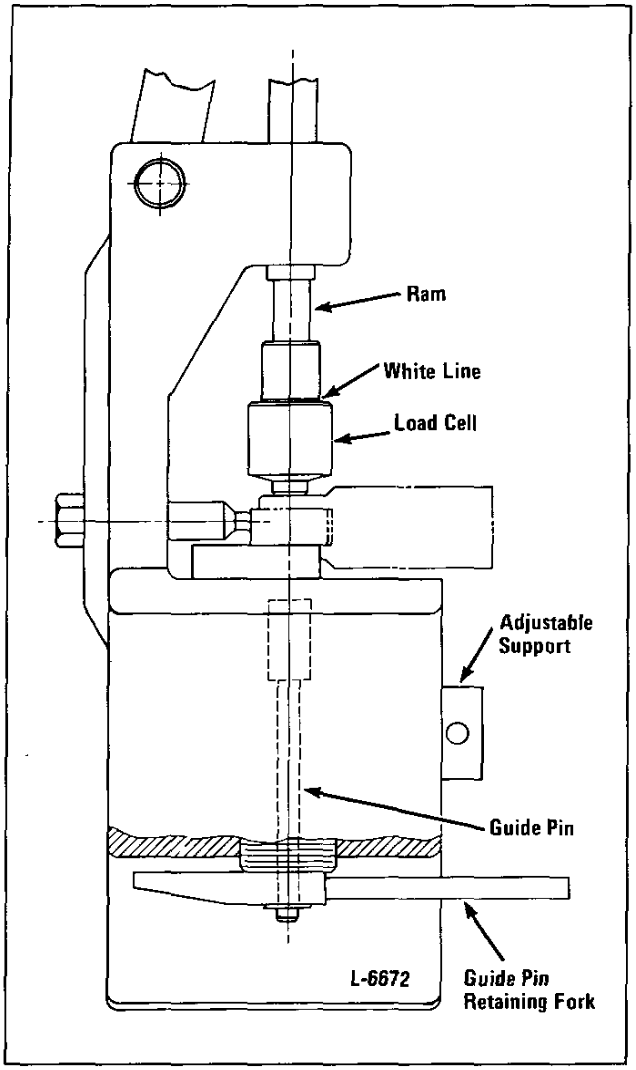
1. Push spring-loaded guide pin (J 33421-12) down and insert fork (J 33421-31) as shown (Fig. 8).

2. Pull support slide (J 33421-2) out, install cam follower, and lower handle, putting slight pressure on roller pin.

3. Push support (J 33421-2) in until resistance is felt.

4. Apply pressure on handle *until white line on load cell just disappears from view.* (300 pounds has now been applied to the roller pin.)

NOTICE: Do not continue downward force after the white line disappears, as load cell will bottom out and eventually push out pin. Do not use the load cell for installation or removal of the roller pin.



• Fig. 8 – Testing Roller Pin on Load Test Cell J 33421-26.

Install Cam Follower and Push Rod

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. *Do not use fuel oil.*

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100–125°F or 38–52°C) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam rollers during the soaking period to purge any air from the bushing–roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

> **NOTICE:** Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from touching the bottom of the pail and avoid the possibility of contamination.

Install used cam followers and push rods in their original locations. Refer to Fig. 9 and proceed as follows:

CYLINDER HEAD ON ENGINE

1. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves, slide the cam follower in position in the cylinder head.

2. Assemble the *serrated* lower spring seat, spring and upper cup–shaped spring seat on the push rod.

   The current cup–shaped upper spring seat can be used with either the former or current spring.

3. Place a flat washer over the upper spring seat and start the locknut on the push rod. Place tool J 3092–01 on the push rod between the washer and the upper spring seat and place the push rod assembly in the cam follower. Then, thread the locknut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Then, install the spring retainer.

4. Remove the nut, flat washer and tool. Then, reinstall the locknut and thread it as far as possible on the push rod.

CYLINDER HEAD REMOVED FROM ENGINE

Refer to Fig. 9 and install the cam follower and push rod as follows:

1. Assemble the *serrated* lower spring seat, spring, upper cup–shaped spring seat and locknut on the push rod.

   The current cup–shaped upper spring seat can be used with either the former or current spring.

2. With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.

3. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves, slide the cam follower in position from the bottom of the head.

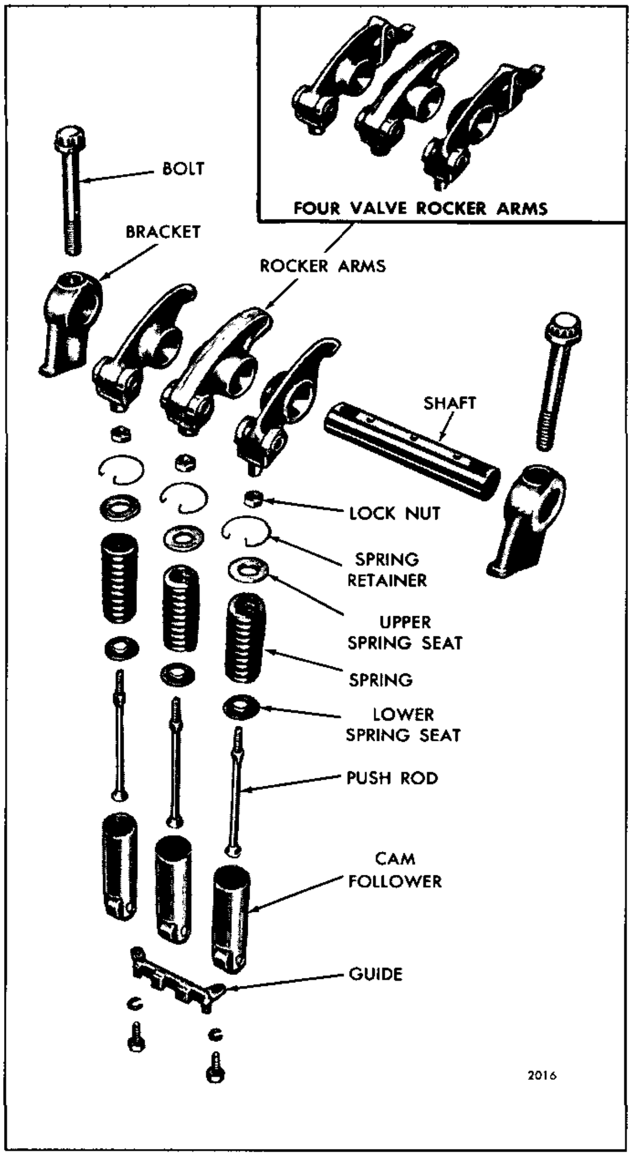


Fig. 9 – Valve and Injector Operating Mechanism and Relative Location of Parts

4. Attach the follower guide to the cylinder head to hold the group of three cam followers in place. Tighten the guide bolts to 12–15 lb-ft (16–20 N·m) torque. Check to be sure there is at least .005″ clearance between the cam follower legs and the cam follower guide (Fig. 10). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 11). Then, retighten the bolts to the specified torque.

NOTICE: It is important to use the correct bolts as prescribed in the parts books. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

Install Rocker Arms and Shaft

Note that the injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the left and right–hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm.

New injector rocker arm assemblies have an increased cross–sectional area between the pivot axis and pallet and the pivot axis and clevis. The former and current rocker arm assemblies are interchangeable and can be mixed in an engine. Only the new assemblies will be serviced.

NOTICE: If the rocker arm is damaged or breaks, the push rod should *always* be changed out when the new rocker arm is installed. A damaged rocker arm can cause side loading and weakening of the push rod. If reused, a side–loaded push rod can break.

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.

2. If removed, install the cylinder head on the engine (refer to Section 1.2).

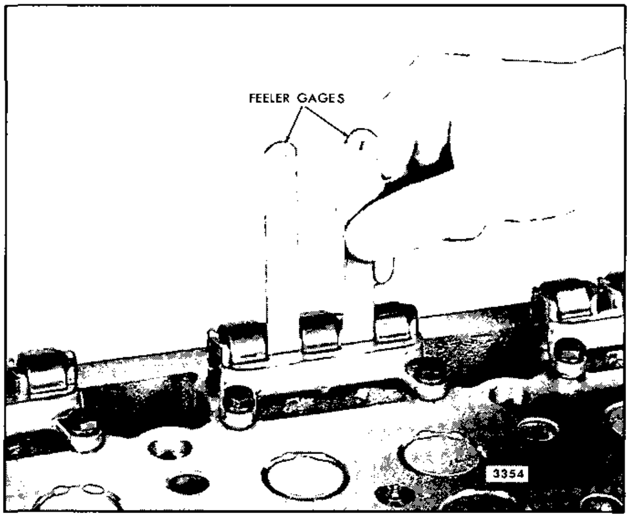


Fig. 10 – Checking Cam Follower to Guide Clearance

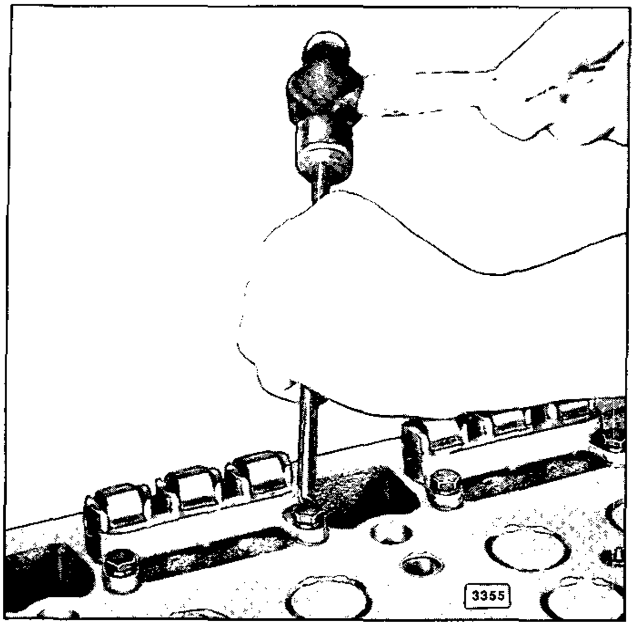


Fig. 11 – Adjusting Cam Follower Guide

3. If removed, install the fuel injectors.

4. Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then, place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.

5. Insert the rocker arm bracket bolts through the rocker cover hold–down bracket (if used) and through the brackets and the shaft (Fig. 12).

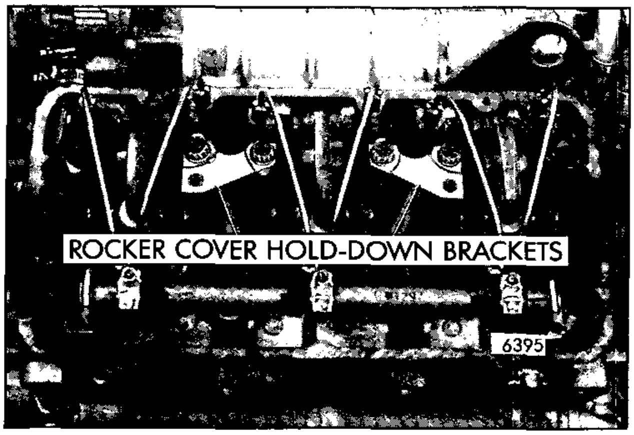


Fig. 12 – Rocker Cover Hold–Down Brackets Mounted on Rocker Arm Shaft Brackets

6. Tighten the rocker arm bracket bolts to the specified torque (refer to Section 1.0). Check to make sure there is some clearance between the rocker arms.

NOTICE: On four–valve cylinder heads, there is a possibility of damaging the exhaust valves if the valve bridge is not resting on the ends of the valves when tightening the rocker arm shaft bracket bolts (Fig. 13). Therefore, note the position of the valve bridges before, during and after tightening the bolts.

• 7. Align the fuel pipes and connect them to the injectors and fuel connectors.

A. *Flared End Fuel Pipes*

NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

NOTICE: *Because of their low friction* surface, Endurion® –coated nuts on fuel pipes must be tightened to 130–***lb–in*** (14.69 N·m) torque, instead of the 160 ***lb–in*** (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening fuel pipe nuts, do not mix lines with uncoated and Endurion®–coated nuts on the same cylinder head.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

B. *O–Ring Sealed Fuel Pipes.* Inspect fuel pipes and connectors carefully. Fuel pipes may be reused if they are not twisted, bent, distorted or otherwise damaged.

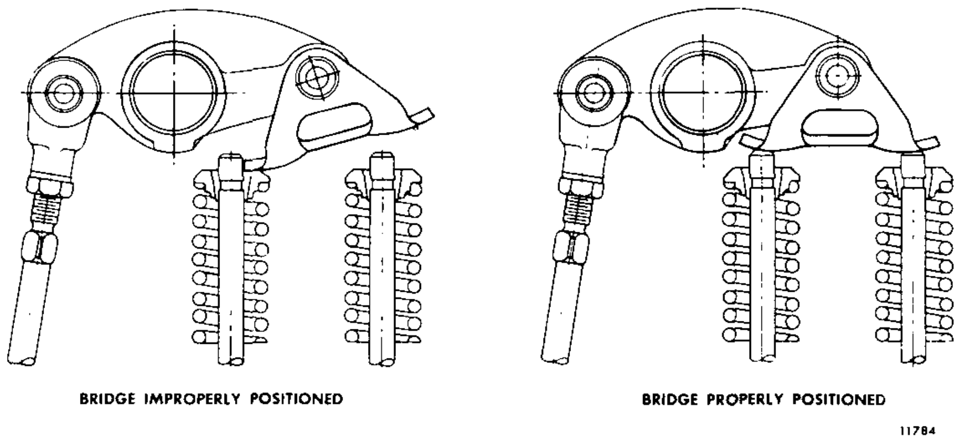


Fig. 13 – Relationship Between Exhaust Valve Bridge and Valve Stems

NOTICE: To avoid fuel leakage, always use new O–ring seals when replacing the fuel pipes on an engine. Do not reuse seals.

Align the fuel pipes and connect them to the injector filter caps and the cylinder head connectors. Using "clicker" type torque wrench J 24405 (calibrated in inch–pounds), tighten the O–ring sealed fuel pipe nuts to 143 ***lb–in*** (16.16 N·m) torque.

Jacobs brake fuel pipes and those used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the chart.

8. Fill the cooling system.

9. Adjust the exhaust valve clearance (Section 14.1) and time the injectors (Section 14.2).

10. If necessary, perform an engine tune–up.

EXHAUST VALVES

Two or four exhaust valves are provided for each cylinder (Fig. 1), depending upon the engine model. The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the rocker arm (two–valve head) or the exhaust valve bridge (four–valve head).

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head. Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves are ground to a 30° seating angle while the exhaust valve seat inserts are ground to a 31° seating angle.

The exhaust valve springs are held in place by the valve spring caps and tapered two–piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leak–proof seating, valve stems must work freely and smoothly within the valve guides and the correct valve clearance (Section 14.1) must be maintained.

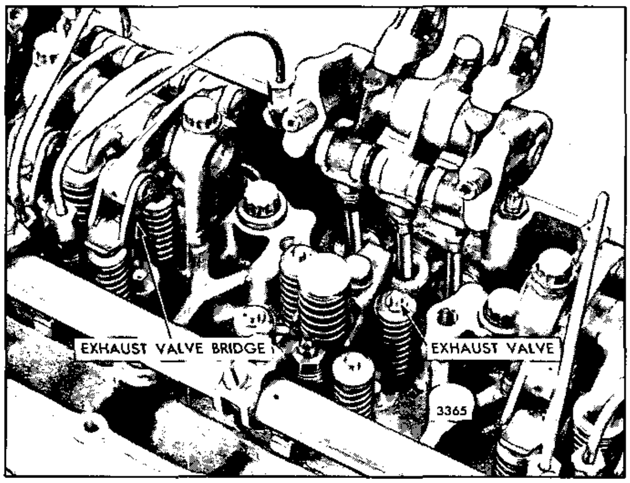


Fig. 1 – Location of Exhaust Valves

Proper maintenance and operation of the engine is important to long valve life. Normal engine operating temperatures should be maintained (see Section 13.2). Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to sludge.

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus, the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters must be changed at the intervals shown in Section 15.1 to avoid the accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems, and bent or worn valve guides. Sticking valves may eventually become bent or broken by being held in the open position and struck by the piston.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion. Excessive valve clearance will result in noisy operation, increased valve face wear, valve and valve lock damage.

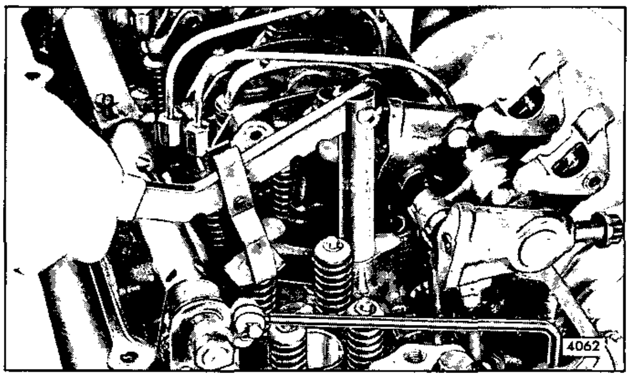


Fig. 2 – Removing Valve Spring Using Tool J 7455

Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Clean and remove the valve rocker cover.
2. Crank the engine over to bring the valve and injector rocker arms in line horizontally.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

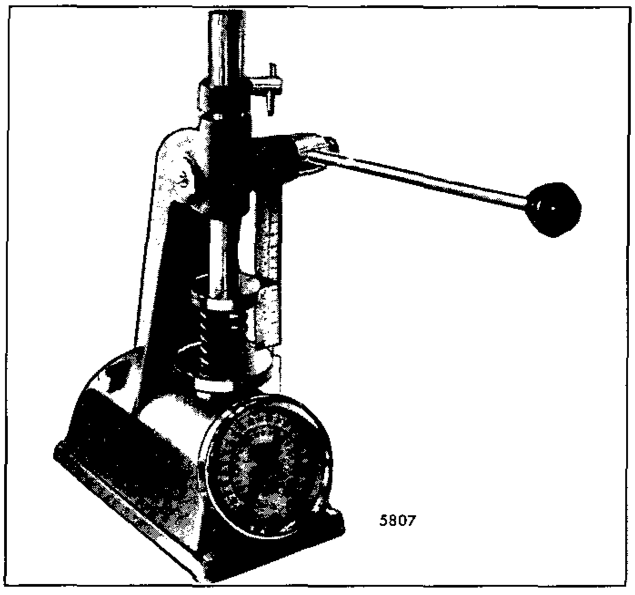


Fig. 3 – Testing Valve Spring Using Tool J 22738–02

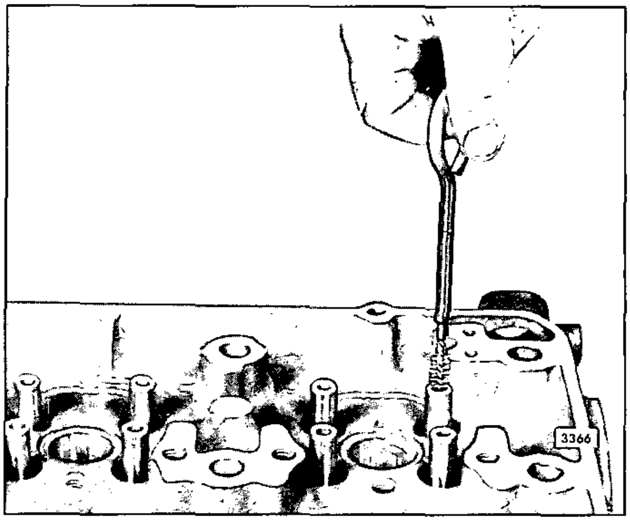


Fig. 4 – Cleaning Valve Guide

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

   NOTICE: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then, remove the brackets and shaft.
5. Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.
6. Thread the valve spring compressor adaptor tool J 7455–4 into one of the rocker arm bracket bolt holes in the cylinder head (Fig. 2). Then, compress the spring and remove the two–piece valve lock.
7. Release the tool and remove the valve spring cap, valve spring and spring seat.

Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs as follows:

1. Support the cylinder head on 2" thick wood blocks to keep the cam followers clear of the bench.
2. Remove the fuel pipes from the injectors and the fuel connectors.

   NOTICE: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then, remove the brackets and the shaft.

4. Remove the fuel injectors.

5. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 6 and 7 above.

6. Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be reused, number each valve to facilitate reinstallation in the same location. Then, withdraw the valves from the cylinder head.

7. Remove the cam followers and push rod assemblies as outlined in Section 1.2.1 under *Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

Inspection

Clean the springs with fuel oil, dry them with compressed air and inspect them. Replace a pitted or fractured spring.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Use spring tester J 22738–02 to check the spring load (Fig. 3). Replace a spring if a load of less than 33 pounds will compress a two valve cylinder head spring to 2.31 inches, or a load of less than 25 pounds will compress a four–valve cylinder head spring to 1.93 inches. The difference in the load between a pair of four–valve cylinder head springs must not exceed 6 pounds or the valve bridge will be unbalanced. *This test will not differentiate between high and low lift valve springs.*

To eliminate exhaust valve spring surge, a new valve spring (.148″ wire diameter) is used in the 4–53 and 6V–53 engines. The change is effective with approximate engine serial numbers 4D–112278 and 6D–82217. The former spring was made from .135″ diameter wire.

- Low lift camshafts must use an exhaust valve spring with a .148″ wire diameter (blue and white paint stripe or solid red color identification). High lift camshafts must use an exhaust valve spring with a .135″ wire diameter (red and green paint stripe identification). A simple gage can be made by cutting a slot approximately .136″ to .138″ wide in a piece of thin steel stock. This will fit over the .135″ wire diameter coil of the high lift spring, but should not fit over the .148″ wire diameter coil of the low lift spring. With this gage, exhaust valve springs are identifiable regardless of color code.

- **NOTICE:** *Do not mix low lift and high lift valve springs on the same engine.* Failure to observe this precaution can result in valve breakage, which may in turn allow the valve to drop into the cylinder, causing extensive cylinder kit damage.

The new spring can be used only in engines built after serial numbers 4D–112278 and 6D–60776 and use the present low–lift camshaft, or older engines which have these low–lift camshafts installed. The low–lift camshaft which provides a maximum valve cam lobe lift of .276″ is metal stamped V7L at both ends.

NOTICE: The use of the new spring with the former high–lift camshaft (.327″ valve cam lobe lift, metal stamped V7 or V at both ends) will cause the valve springs to bottom out, resulting in bent push rods and possible engine damage.

For service replacement, change the new spring when a load of less than 25 lbs. will compress it to 1.93″ (installed length).

The new and former valve springs are interchangeable in an engine rated below 2800 rpm using a low–lift (V7L) camshaft. However, on any given valve bridge, it is recommended that both springs be the same.

When a former spring is replaced in an engine rated at 2800 rpm with a low–lift (V7L) camshaft, all of the springs must be replaced with the new spring.

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

Carbon on the face of a valve could indicate blow–by due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures. High operating temperatures are normally due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil.

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

Effective with four valve cylinder head engines built the second quarter of 1980, a new exhaust valve guide oil seal is being used. The new oil seal (Fig. 18) has a metal case and the slightly reduced inner diameter of the seal provides a press fit on the valve guide. The former oil seal was retained by a spring at the small end and a retainer at the large end. The former and current oil seals are interchangeable on a cylinder head.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. Ifnecessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

Clean the inside diameter of the valve guides with brush J 5437 (two–valve head), or brush J 7793 (four–valve head) – (Fig. 4). This brush will remove all gum or carbon deposits from the valve guides, including the spiral grooves.

Inspect the valve guides for fractures, chipping, scoring or excessive wear. Measure the valve guide inside diameter with a pin gage or inside micrometer and record the readings. After inspecting and cleaning the exhaust valves, measure the outside diameter of the valve stems with a micrometer and record the readings. Compare the readings to obtain the valve–to–guide clearance. If the clearance exceeds .006" (two–valve head) or .005" (four–valve head), replace the valve guides.

Replace Exhaust Valve Guide

Remove the exhaust valve guide as follows:

1. Remove and discard the oil seal, if used.

2. Support the cylinder head, bottom side up, on 3" thick wood blocks.

   Drive the valve guide out of the cylinder head with valve guide remover J 6569 (two–valve head) or J 7775 (four–valve head) – (Fig. 5).

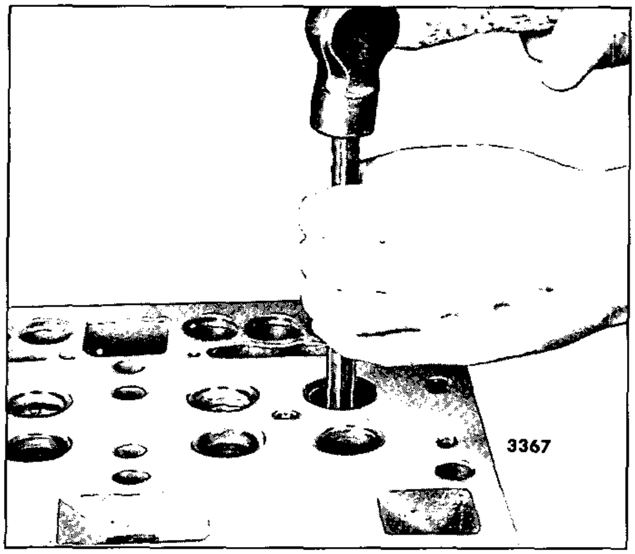


Fig. 5 – Removing Valve Guide

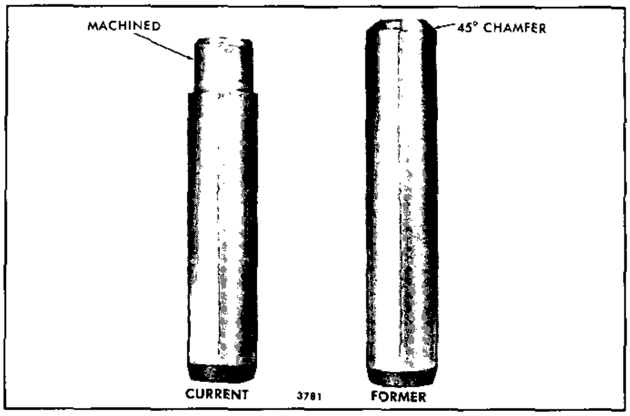


Fig. 6 – Former and Current Valve Guides

The current valve guides have a 45° chamfer at the top, replacing the former guides with a 15° chamfer. In addition, the guide for the four–valve cylinder head is machined for use of an oil seal (Fig. 6).

Install the exhaust valve guide as follows:

1. Place the cylinder head right side up on the bed of an arbor press.

2. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to the *Valve Guide Installing Tools* Chart (Fig. 7). When replacing the exhaust valve guides in a cylinder head, the current guide which is machined for use with an oil seal should be used in place of the 45° chamfered guide (Fig. 6). The current guide will facilitate field installation of valve guide oil seals.

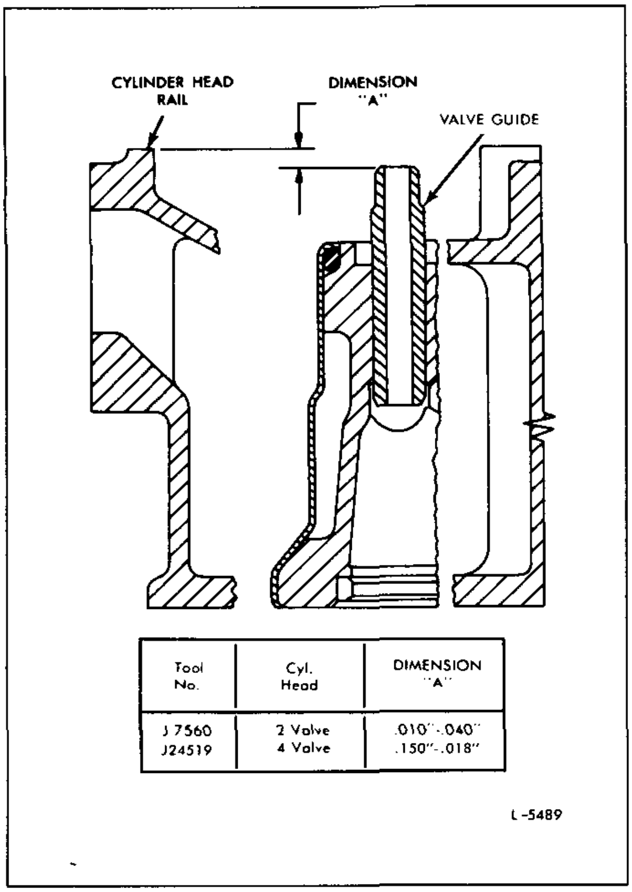
   NOTICE: Be sure to use the correct tool to avoid damage to the valve guide and to locate the valve guide to the proper dimension.

3. Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (Fig. 8). Then, press the guide in until the tool contacts the cylinder head (the bottom of the counterbore in the four–valve cylinder head).

   NOTICE: Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Inspect Exhaust Valve Seat Insert

Inspect the exhaust valve seat inserts for excessive wear, pitting or cracking.



Tool No.	Cyl. Head	DIMENSION "A"
J 7560	2 Valve	.010"-.040"
J24519	4 Valve	.150"-.018"

Fig. 7 – Valve Guide Installing Tools

Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder head and must be removed as outlined in the following procedure to avoid damage to the cylinder head:

1. Using puller assembly from tool set J23479–E, screw collet handle into collet J23479–27 (2–valve) or J 23479–28 (4–valve) and assemble in puller as shown (Fig. 9).

2. With cam handle in lax position (low point of cam contacting receiver body), expand collet by tightening tapered nut until pulling lip of collet just slips through valve seat insert.

3. Hold handle in lax position and install collet portion into valve seat insert.

4. While holding receiver body down and square with cylinder head, pull cam handle down until resistance is felt and hold. *Rotate Cam Only in Direction of Arrow.*

5. While holding cam handle down with one hand, grasp the collet handle with the other hand and rotate back and forth several times. This will scrape carbon from beneath the insert and permit the operator to determine proper engagement of the collet.

6. Transfer grasp from collet handle to receiver body and continue pulling cam handle down until insert is removed.

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the head with 1,1,1–Trichlorethane or other suitable solvent. Also, wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.

   - **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

2. Inspect the counterbores for cleanliness, concentricity, flatness and cracks. The counterbores for the valve seat inserts in a two–valve head have a diameter of 1.439" to 1.440" and a depth of .294" to .306". The counterbores for the valve seat inserts in a four–valve head have a diameter of 1.159" to 1.160" and a depth of .294" to .306" on former engines and a depth of .300" to .312" on current engines.

   Valve seat inserts which are .010" oversize on the outside diameter are available, if required.

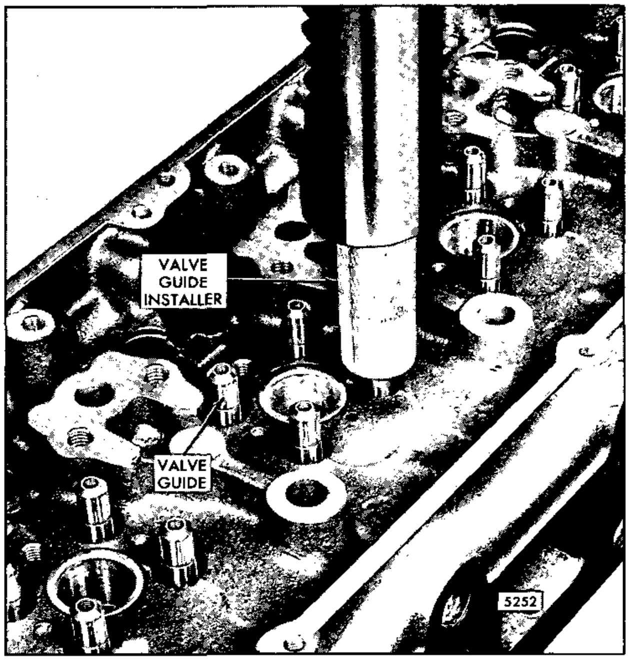
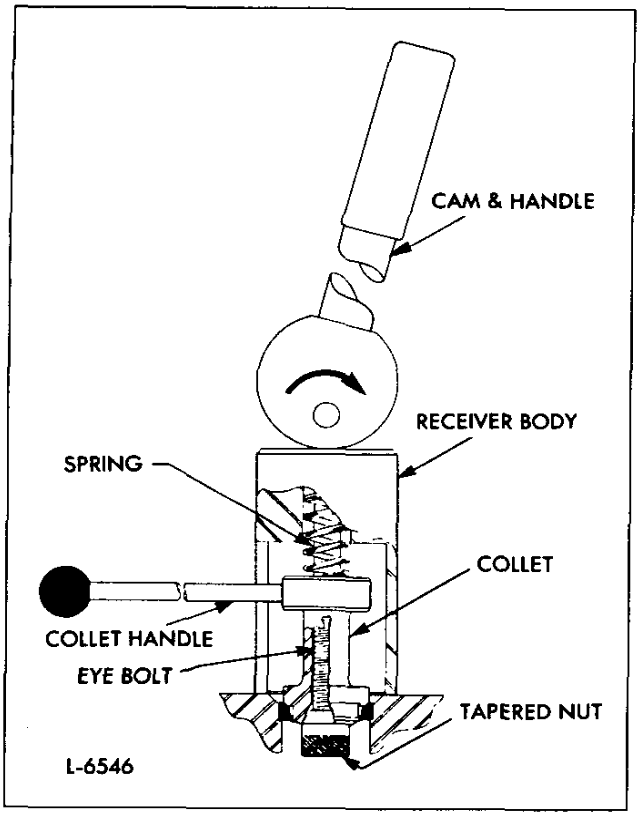


Fig. 8 – Installing Valve Guide



• Fig. 9 – Removing Valve Seat Insert

3. Immerse the cylinder head for at least 30 minutes in water heated to 180–200°F (82–93°C).
4. Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore—valve seat side up. This must be done quickly while the cylinder head is still hot and the insert is cold (room temperature). If the temperature of the two parts is allowed to become nearly the same, installation may become difficult and damage to the parts may result.
5. Drive the insert in place with installer J 6976 (two–valve head) or J 7790 (four–valve head) – (Fig. 10) until it seats solidly in the cylinder head.
6. Grind the old valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

   Because the new preground exhaust valve seat inserts are prefinished, they need only be checked for concentricity after proper installation. Grinding is required only if the runout exceeds .002″.

Recondition Exhaust Valve and Valve Seat Insert

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 11). To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than 1/32″ in thickness and must still be within the specifications shown in Figs. 13 and 14 after refacing.

Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating. The proper angle for the seating face of the valve is 30° and for the valve seat insert, it is 31°.

When a new valve seat insert is installed or an old insert refaced, the work must be done with a grinding wheel (Fig. 12).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work .001″ at a time.

To grind the valve seat inserts for a two–valve cylinder head, use the following tools:

1. Grinder J 8165–1
2. Dial Gage J 8165–2
3. Pilot J 7659–1
4. Grinding Wheel (15°) J 7924–1
5. Grinding Wheel (31°) J 7924–2
6. Grinding Wheel (60°) J 7924–3

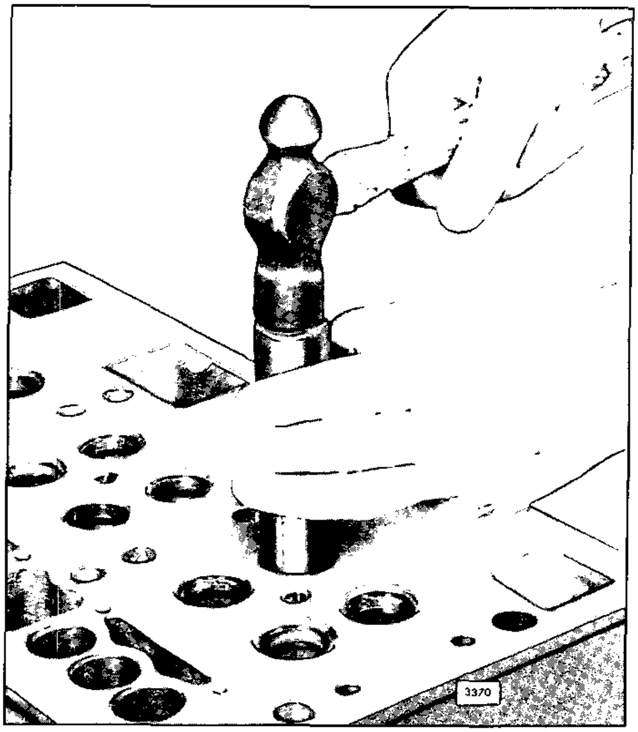


Fig. 10 – Installing Valve Seat Insert

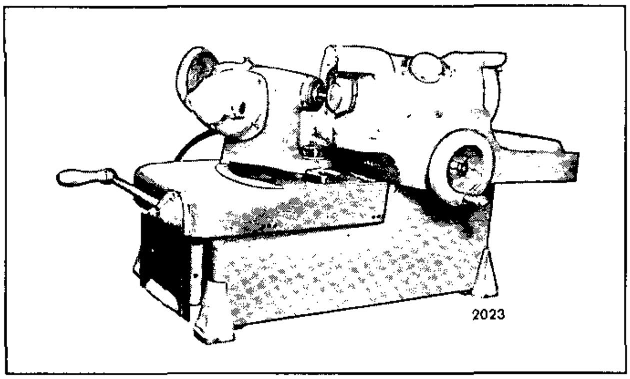


Fig. 11 – Refacing Exhaust Valve

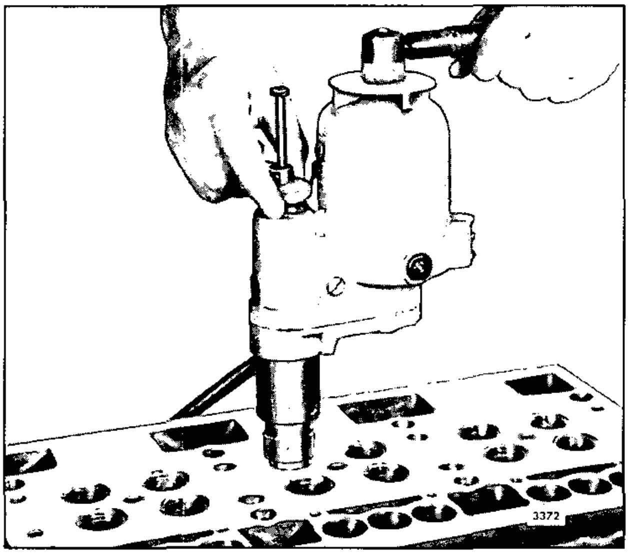


Fig. 12 – Grinding Valve Seat Insert

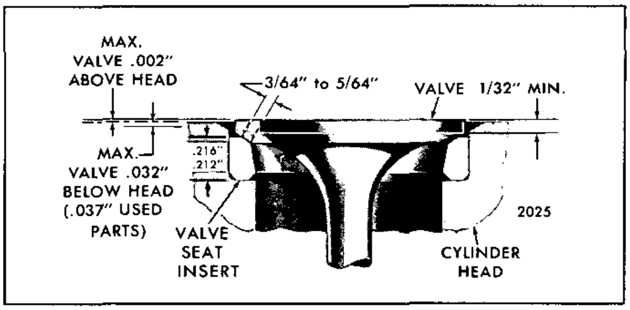


Fig. 13 – Relationship Between Exhaust Valve, Insert and Cylinder Head (Two-Valve Head)

To grind the valve seat inserts for a four-valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7792-1
4. Grinding Wheel (15°) J 7792-2
5. Grinding Wheel (31°) J 7792-3
6. Grinding Wheel (60°) J 7792-4

Grind the valve seat inserts as follows:

1. First apply the 31° grinding wheel on the valve seat insert.
2. Use the 60° grinding wheel to open the throat of the insert.

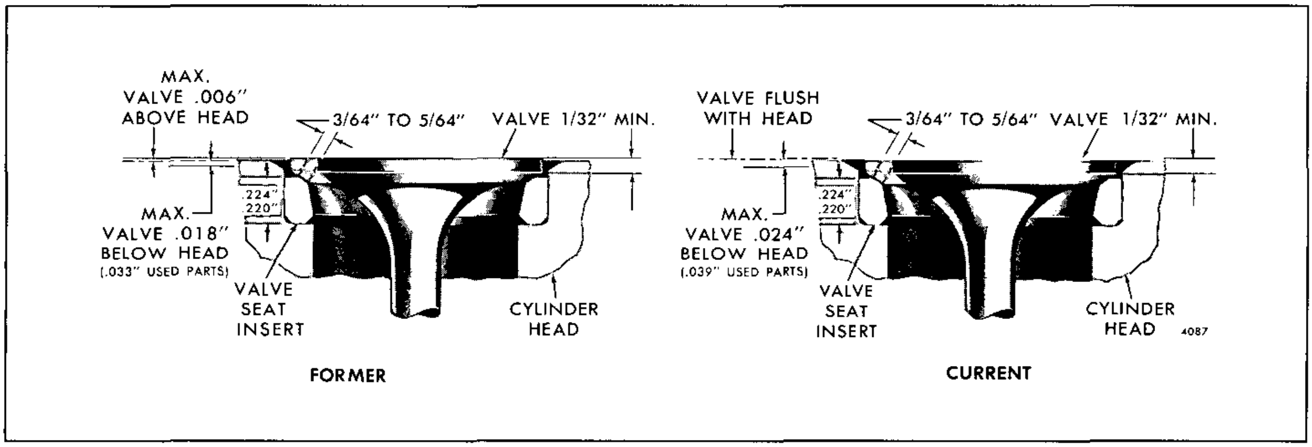


Fig. 14 – Relationship Between Exhaust Valve, Insert and Cylinder Head (Four-Valve Head)

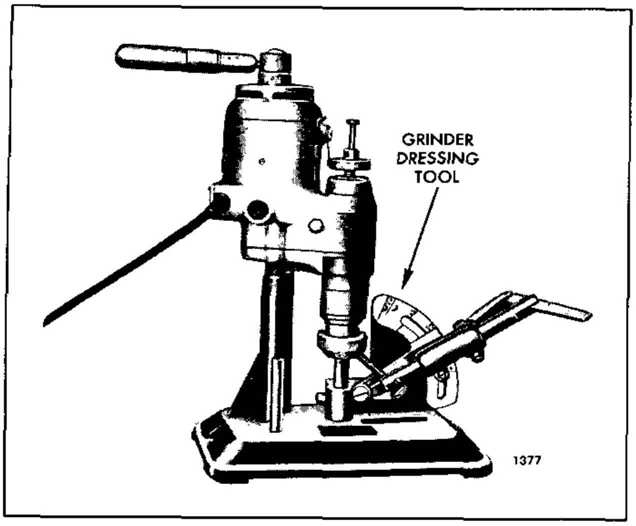


Fig. 15 – Grinding Wheel Dressing Tool of Set J 8165–1

3. Then, grind the top surface with a 15° wheel to narrow the width of the seat from 3/64" to 5/64" (Figs. 13 and 14). The 31° face of the insert may be adjusted relative to the center of the valve face with the 15° and 60° grinding wheels. *Do not permit the grinding wheel to contact the cylinder head when grinding the insert. If necessary, replace the insert.*

   The maximum amount that the exhaust valve should protrude beyond the cylinder head (when the valve is in the closed position), and still maintain the proper piston–to–valve clearance (Figs. 13 and 14). Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

   When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig. 15).

   After grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165–2 in position (Fig. 16) and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. If the runout exceeds .002", check for a bent valve guide before regrinding the insert.

4. After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

   a. Apply a light coat of Prussian Blue or similar paste to the valve seat insert. *The use of valve lapping compound is not recommended.*

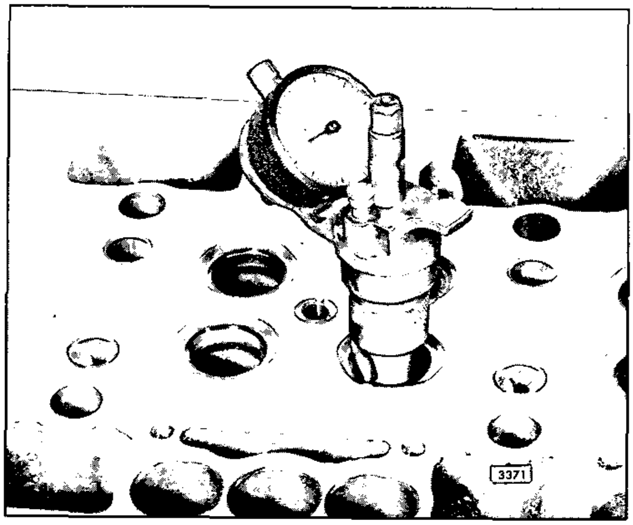


Fig. 16 – Checking Relative Concentricity at Valve Seat Insert with Relation to Valve Guide

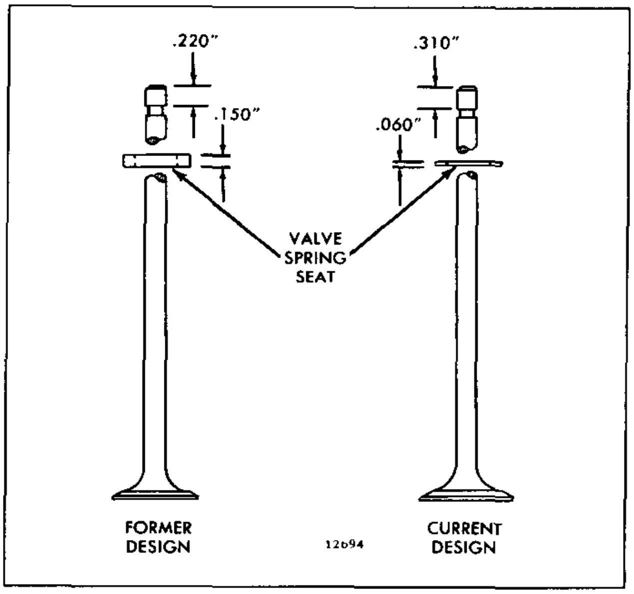


Fig. 17 – Former and Current Design Exhaust Valves (Four–Valve Head)

   b. Lower the stem of the valve in the valve guide and "bounce" the valve on the seat. *Do not rotate the valve.*

This procedure will show the area of contact (on the valve face). The most desirable area of contact is at the center of the valve face.

After the valve seat inserts have been ground and checked, thoroughly clean the cylinder head before installing the valves.

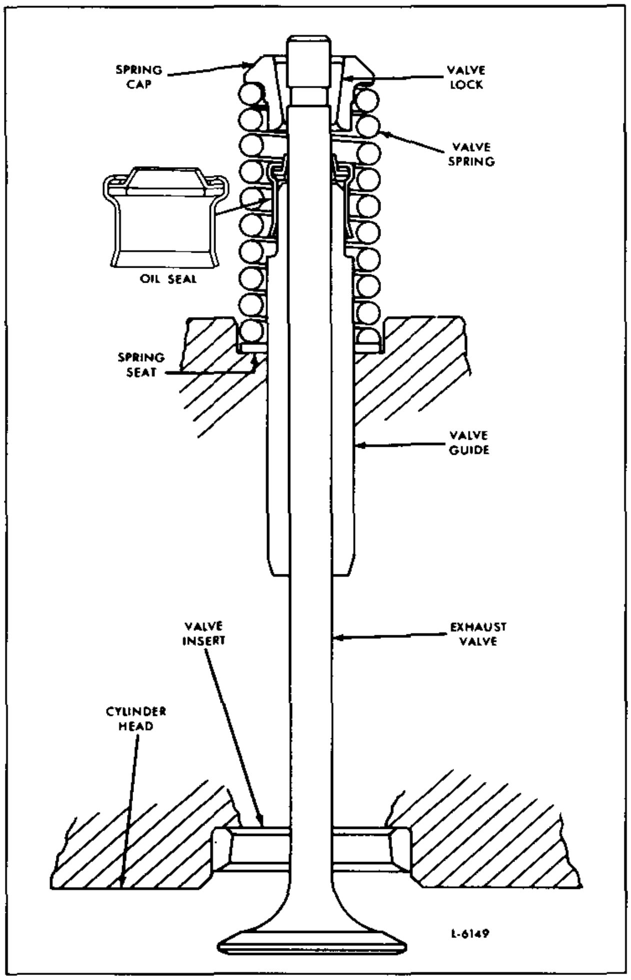


Fig. 18 – Current Valve Guide Oil Seal

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications (Figs. 13 and 14). Also, do not use "N" pistons with former four–valve cylinder head assemblies unless the valves are flush with the cylinder head. If the valves are not flush, it may be necessary to regrind the valve seats so that the valves will be flush with the bottom surface of the cylinder head.

The distance from the top of the four–valve cylinder head to the bottom of the valve spring seat counterbore is 1.175″ ± .015″ in current design cylinder heads or 1.078″ ± .015″ in former design heads. The former head was discontinued in May, 1971.

Be sure and install the correct parts in the four–valve cylinder head. Current design cylinder heads are equipped with the thin valve spring seats (.060″) and current design exhaust valves (Fig. 17). To facilitate replacement of a four–valve head on an engine using the former exhaust valves, the proper quantity of the thick spring seats (.150″) must be used.

Service cylinder heads are of the current design. The current thin valve springs seats (.060″) are included with each cylinder head as a shipped loose item.

Install exhaust valves as follows:

1. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides. *If reconditioned valves are used, install them in the same relative location from which they were removed.*
2. Hold the valves in place temporarily with a strip of masking tape. Then, turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.
3. Install the valve spring seats.
4. Install the valve guide oil seals, if used, on the valve guides as follows:
   a. Lubricate the oil seal and the valve stem with engine oil and start the oil seal carefully over the valve stem.

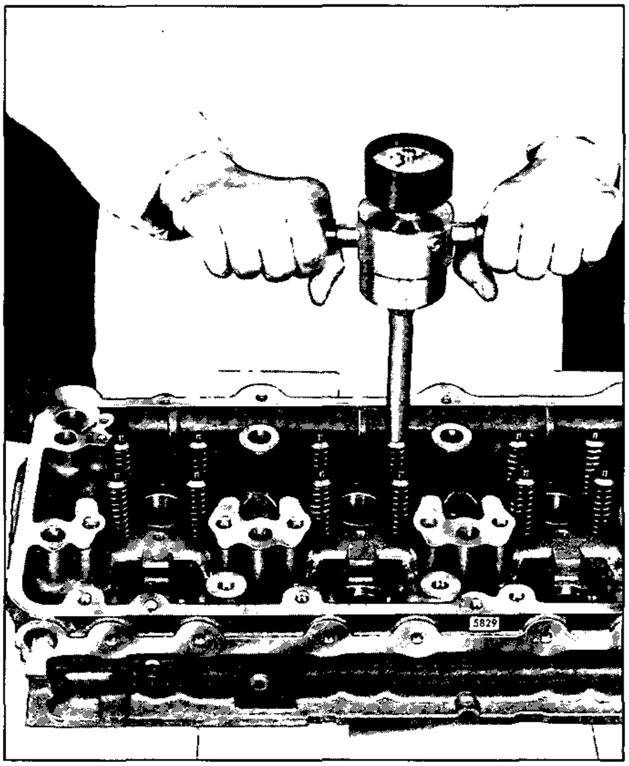


Fig. 19 – Checking Valve Opening Pressure with Gage J 25076–B

b. Using installer J 29579 drive the seal down slowly until the tool bottoms on the cylinder head (spring seat washer removed). Then, tap the tool with a mallet for final location and seating of the seal.

NOTICE: The tool positions the seal so that it does not bottom out on the shoulder of the valve guide. If the oil seal is installed too far, it will be distorted and will not function as an effective seal.

c. Install the spring seat washer over the valve guide and let it drop into the valve counterbore (Fig. 18).

5. Install the valve springs and valve spring caps.

6. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 2).

7. Apply pressure to the free end of the tool to compress the valve spring and install the two–piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

NOTICE: If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

8. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

9. Check the position of the exhaust valve (Figs. 13 and 14).

10. Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then, give the ends of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

11. With the exhaust valves installed in the cylinder head, use spring checking gage J 25076–B and note the gage reading the moment the exhaust valve starts to open (Fig. 19). The minimum pressure required to start to open the exhaust valve must not be less than 33 pounds for a two–valve cylinder head or 25 pounds for a four–valve cylinder head.

12. Install the injectors, rocker arms, shafts, brackets and any other parts that were previously removed from the cylinder head.

13. Install the cylinder head. Refer to *Pre–Installation Inspection* and *Install Cylinder Head* in Section 1.2.

14. Perform a complete engine tune–up.

VALVE ROCKER COVER

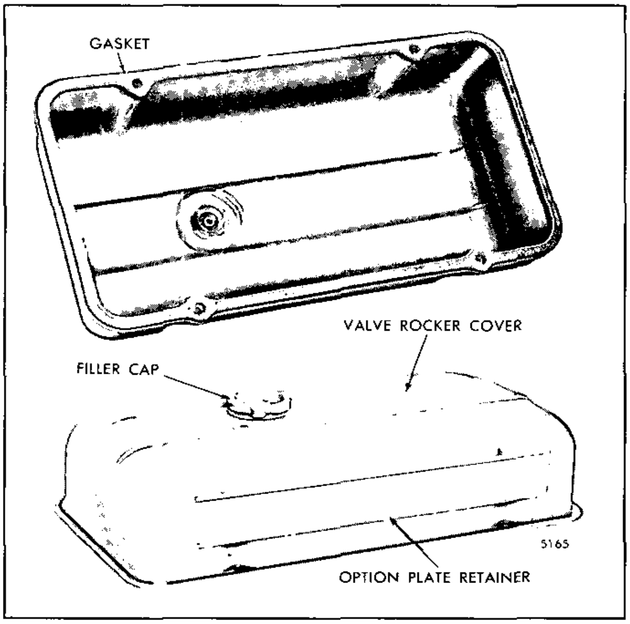


Fig. 1 – Typical Stamped Steel Valve Rocker Cover Assembly

The valve rocker cover assembly completely encloses the valve and injector rocker arm compartment at the top of the cylinder head (Figs. 1 and 2). The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

• An option label is attached to the cover on each In–line engine and to one of the covers on a V–type engine. An option plate inserted into a retainer (Fig. 2) was formerly used.

The valve rocker cover assembly on certain engines may include a breather assembly or an oil filler, depending upon the engine application.

Remove and Install Valve Rocker Cover

Clean the valve rocker cover before removing it from the engine to keep dust or dirt from entering the valve mechanism. Then, loosen the bolts (cast aluminum rocker cover) or the screws (stamped steel rocker cover) and lift the cover straight up from the cylinder head. Use a new gasket when reinstalling the cover.

• Before a die cast rocker cover is installed on a cylinder head, it is important that the silicone gasket be properly installed in its groove in the rocker cover.

1. Clean and blow out the groove in the rocker cover with compressed air. Oil in the rocker cover groove or on the silicone gasket will make it difficult to install.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

2. Press the stem side of the new T–shaped gasket down into the groove at the four corners of the cover first. Then press the remainder of the gasket into place in the groove. Be sure the stem of the entire gasket bottoms in the groove. When the gasket is completely installed in the groove it should not fall out.

3. Before installing the rocker cover, lubricate the cylinder head rail and the flat surface of the gasket with a thin film of engine oil. This will keep the gasket from sticking to the cylinder head rail.

4. Tighten the 3/8"–16 cast aluminum rocker cover hold–down bolts to 8–13 lb–ft (11–18 N·m) torque. Do not overtighten.

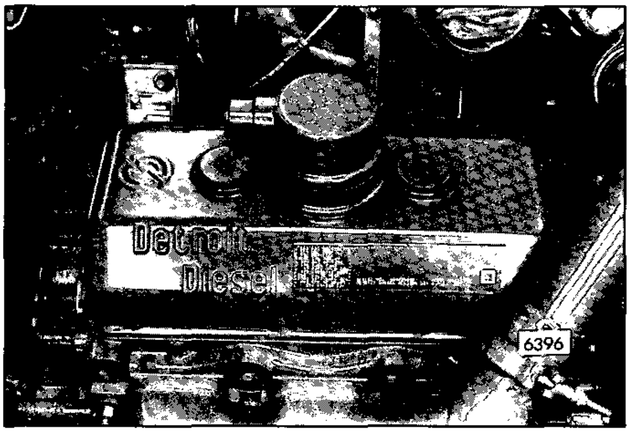


Fig. 2 – Die–Cast Aluminum Rocker Cover on 6V–53T Engine (Former Option Plate Shown)

CRANKSHAFT

The crankshaft is a one–piece steel forging, heat–treated to ensure strength and durability (Figs. 1 and 2). All main and connecting rod bearing journal surfaces, oil seal surfaces and fillets on the 4–53 vehicle engine (since 4D–146948) and 6V crankshafts are induction hardened. All Series 53 engine crankshaft fillets are now induction hardened effective with 3D–187345 and 4D–201209 (non–vehicle engines).

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

On certain 4–53 and 6V engines, a crankshaft with splines at the front end is used. These engines use a splined crankshaft pulley and pulley mounting components.

On In–line and 6V engines, six tapped holes are provided in the rear end of the crankshaft for attaching the flywheel.

On the 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel and six tapped holes are provided for attaching the flywheel. One hole is unequally spaced so that the flywheel can be attached in only one position.

The 8V engine crankshaft no longer incorporates the two dowels in the flywheel end of the crankshaft. However, the former and current crankshafts are interchangeable.

In–line engine main bearing journals are 3.000" in diameter and the connecting rod journals are 2.500" in diameter. On the V–type engine, the main bearing journals are 3.500" in diameter and the connecting rod journals are 2.750" in diameter.

Effective with 8V engine serial number 8D–149, the 2.878" diameter position at the front of the crankshaft serves as a journal for the outboard bearing (bushing type). A spacer (sleeve) is used on the 2.500" diameter position to provide a replaceable contact surface for the front oil seal which is located in the outboard bearing support assembly. Prior to engine 8D–149, the 2.878" diameter position served as a contact surface for the front oil seal assembled in the front cover.

Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Clean the exterior of the engine.
2. Drain the cooling system.
3. Drain the engine crankcase.
4. Remove all engine–to–base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets at each end of the engine, remove the engine from its base.

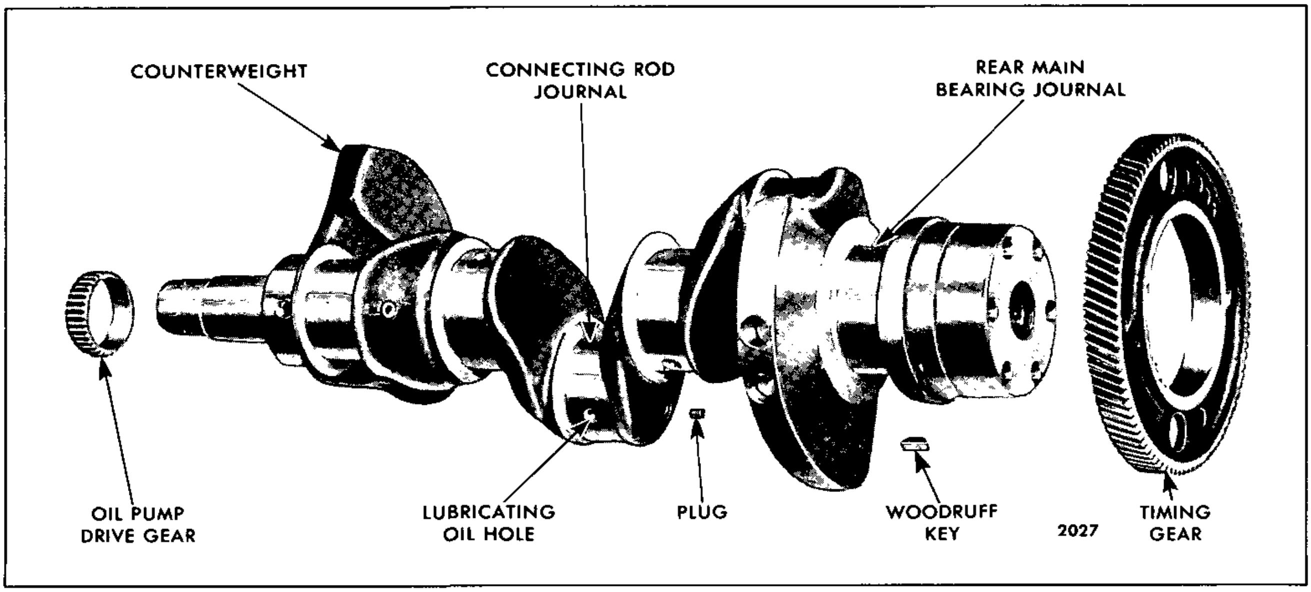


Fig. 1 – Crankshaft Details and Relative Location of Parts (3–53 Crankshaft Shown)

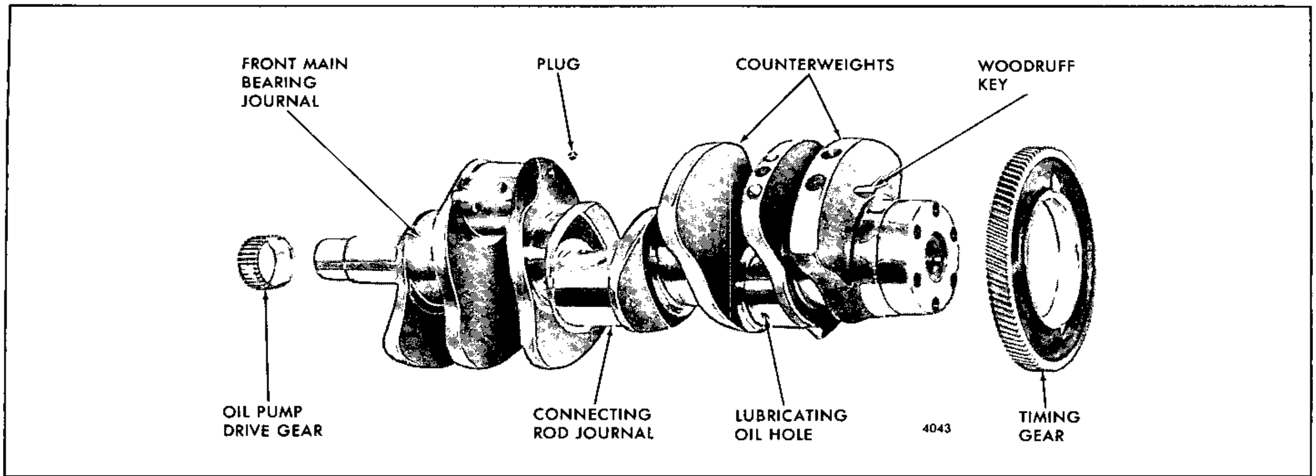


Fig. 2 – Crankshaft Details and Relative Location of Parts (6V Crankshaft Shown)

5. Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.

6. Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

CAUTION: Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan.

8. Remove the oil pump inlet pipe and screen.

9. Remove the flywheel and flywheel housing.

CAUTION: Extreme caution should be used when removing a flywheel by either leaving one or two bolts in the flywheel, or installing two suitable guide pins to support the flywheel until a lifting tool or some other suitable safe lifting device is attached to the flywheel.

10. Remove the crankshaft pulley.

11. Remove the front engine support.

12. Remove the engine lower front cover and oil pump assembly.

13. Remove the cylinder head(s).

14. On the V–type engines, remove the main bearing cap stabilizers.

15. Remove the connecting rod bearing caps.

16. Remove the main bearing caps.

17. Remove the thrust washers from each side of the rear main bearing.

18. Remove the pistons, connecting rods and liners.

19. Remove the crankshaft, including the timing gear (Fig. 3).

20. Refer to Section 1.7.5 for removal of the crankshaft timing gear and Section 4.1 for the procedure covering removal of the oil pump drive gear.

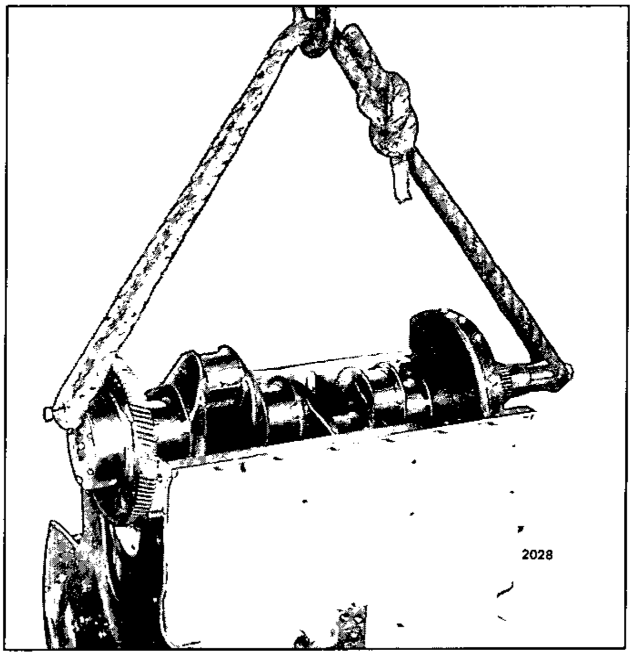


Fig. 3 – Removing or Installing Crankshaft

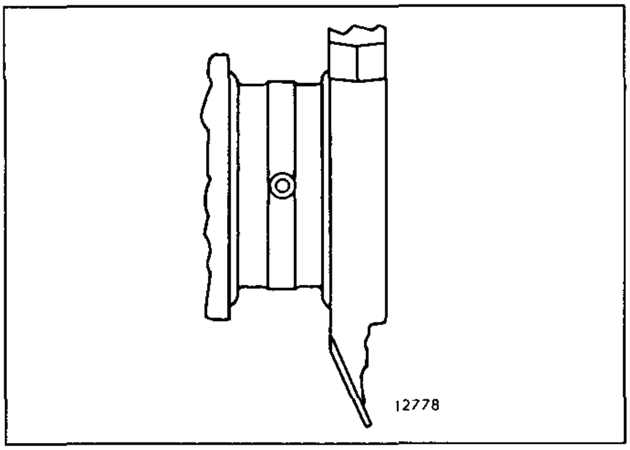


Fig. 4 – Typical Ridging of Crankshaft

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then, reinstall the plugs and torque to 10–12 lb–ft (14–16 N·m). Use tool J 34650 to install the new sealant–coated 1/8"–27 pipe plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 4). Ridges exceeding .0002" must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005", first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out–of–round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001", the crankshaft may have to be reground.

Carefully, inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seal may be repositioned in the flywheel housing and front cover as outlined in Section 1.3.2.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise, it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

On an 8V engine, check the crankshaft dowel extension. The dowels should not extend more than .500" from the crankshaft.

Inspect the crankshaft for cracks as outlined under *Inspection for Cracks.*

Crankshaft Measurements

Support the crankshaft on its front and rear journals on V–blocks, in a lathe or the inverted engine block with only the front and rear upper bearing shells in place and check the alignment at the adjacent intermediate main journals with a dial indicator.

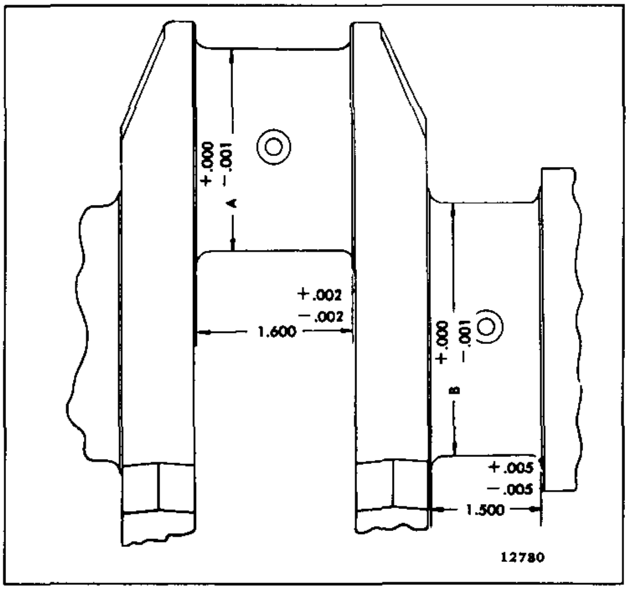


Fig. 5 – Dimensions of Crankshaft Journals – In–Line Engine

On 2–53, 3–53, 4–53 and 6V crankshafts, the *maximum runout on the intermediate journals must not* exceed .002" total indicator reading.

On an 8V crankshaft, the maximum runout at the No. 2 and 4 journals must not exceed .002", the maximum runout at No. 3 journal must not exceed .004" and the maximum runout on the outboard journal must not exceed .001"

On the 6V and 8V crankshaft, when the high spots of runout on the adjacent journals is in opposite directions, the *sum must not exceed .003" total indicator reading.* When the high spots of runout on the adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When the high spots of runout on the adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .002" on each journal. If the runout limit is greater than given above, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing journals (Figs. 5 and 6). Measure the journals at several *places on the circumference so that taper, out–of–round and* bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod journal–to–bearing shell clearance (with new shells) exceeds .0045" (In–line engine) or .0041" (V–type engine) or the main bearing journal–to–bearing shell clearance (with new shells) exceeds .0040" (In–line and V–type engines), the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper or the out–of–round is greater than .003", the crankshaft must be reground.

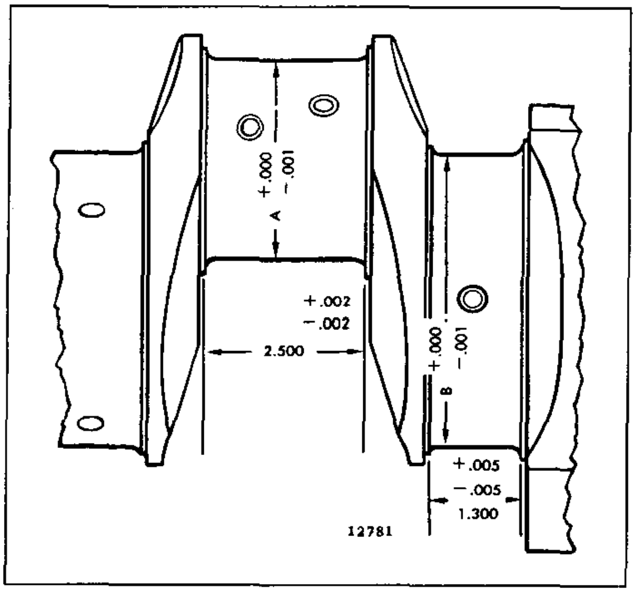


Fig. 6 – Dimensions of Crankshaft Journals – V–Type Engine

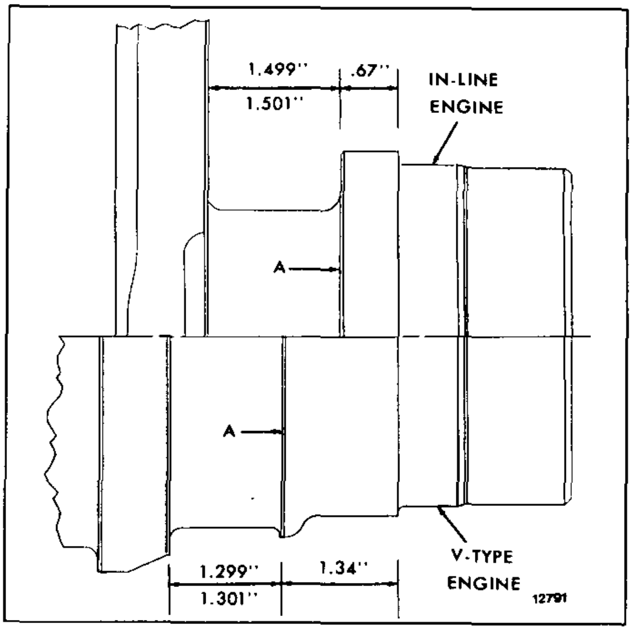


Fig. 7 – Standard Dimensions at Crankshaft Thrust Surfaces — In–Line and V–Type Engines

Also, measure the crankshaft thrust surfaces (Fig. 7).

Inspection for Cracks

Carefully, check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

Magnetic Particle Method: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be demagnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "black light".

Fluorescent Penetrant Method: This is a method which may be used on both *non–magnetic and magnetic* materials. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "black–light".

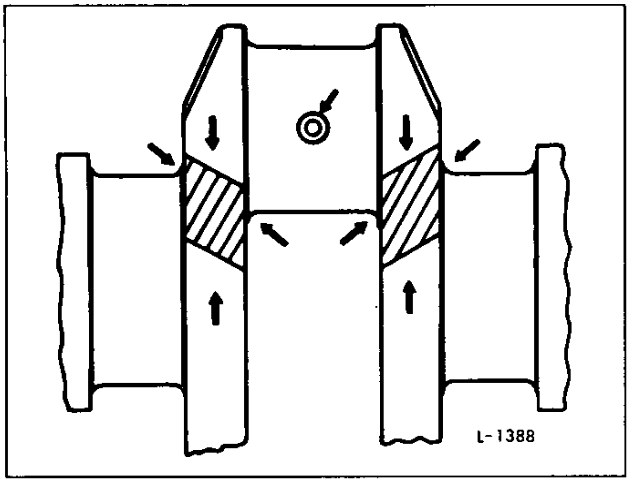


Fig. 8 – Critical Crankshaft Loading Zones

Non–Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this even developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the *harmless indications with the same intensity as the harmful* ones, detection of the indications is but a first step in the procedure. **Interpretation** of the indications is the most important step.

All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service — a *bending* force and a *twisting* force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 8).

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 8.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal oil holes (Fig. 9). Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002", .010", .020" and .030" undersize bearings are available. The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

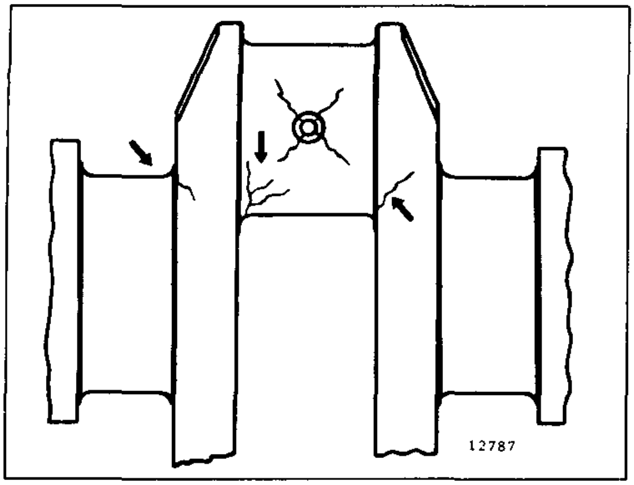


Fig. 9 – Crankshaft Fatique Cracks

Crankshaft main bearing journals and/or connecting rod journals which exhibit discoloration due to excessive overheating from bearing failure are not acceptable for rework.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 1 and Figs. 5 or 6 and determine the size to which the journals are to be reground.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
In-Line Engines		
Standard	2.499"/2.500"	2.999"/3.000"
.002" Undersize	2.497"/2.498"	2.997"/2.998"
.010" Undersize	*2.489"/2.490"	*2.989"/2.990"
.020" Undersize	*2.479"/2.480"	*2.979"/2.980"
.030" Undersize	*2.469"/2.470"	*2.969"/2.970"
V-Engines		
Standard	2.749"/2.750"	3.499"/3.500"
.002" Undersize	2.747"/2.748"	3.497"/3.498"
.010" Undersize	*2.739"/2.740"	*3.489"/3.490"
.020" Undersize	*2.729"/2.730"	*3.479"/3.480"
.030" Undersize	*2.719"/2.720"	*3.469"/3.470"

*Dimension of reground crankshaft

TABLE 1

2. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.

3. All journal fillets on the In–line crankshafts must have a .130" to .160" radius and on the 6V and 8V *crankshafts, a .100" to .130" radius between the crank* cheek and the journal and must not have any sharp grind marks (Fig. 10). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. Polish the ground surfaces to an 8–12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

6. If the thrust surfaces of the crankshaft (Fig. 7) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130" to .160" radius on the In–line crankshaft and .100" to .130" radius on the 6V and 8V engines between each thrust surface and the bearing journal.

7. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32".

8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

9. Demagnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

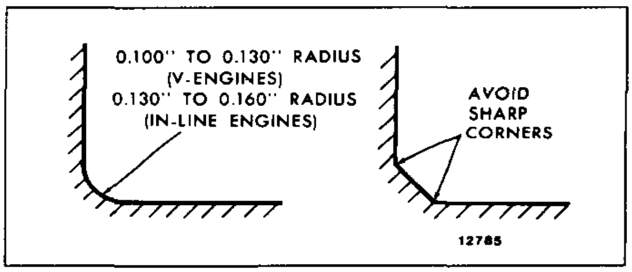


Fig. 10 – Crankshaft Journal Fillets

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then, install the crankshaft as follows:

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.

2. Refer to Section 1.3.4 for main bearing details and install the upper *grooved* main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed. When a new or reground crankshaft is installed, *ALL* new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

3. Apply clean engine oil 360° around all crankshaft bearing journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.

4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. *The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.* If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 7 and Table 2.

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1240"	.1270"
.010" Oversize	.1290"	.1320"

TABLE 2

5. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

6. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4. If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

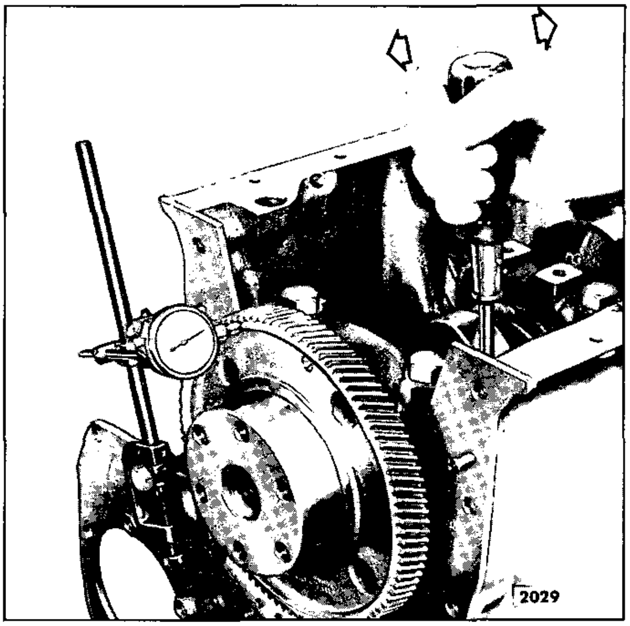


Fig. 11 – Checking Crankshaft End Play

7. Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 11) with a small (less than 12") pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then, remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004" to .016" with new parts or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).

9. Install the cylinder head(s) (Section 1.2).

10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).

11. Install the crankshaft lower engine front cover and oil pump assembly on In–line and 6V engines or the engine front cover and outboard bearing support on 8V engines (Section 1.3.5).

12. Install the engine front support, if used.

13. Install the crankshaft pulley (Section 1.3.7).

14. Install the oil pump inlet pipe and screen on In–line and 6V engines; on the 8V engines, install the oil pump, inlet pipe and screen assembly (Section 4.1).

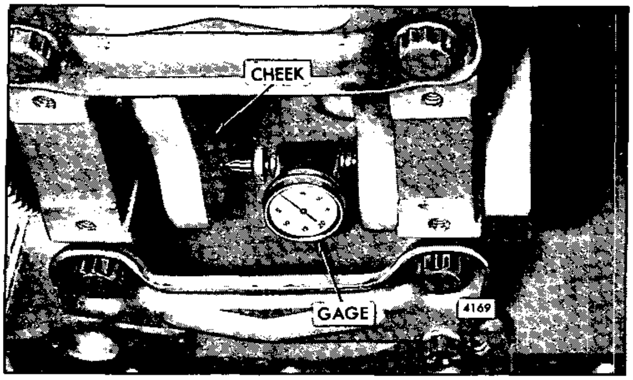


Fig. 12 – Crankshaft Distortion Measuring Gage Mounted on Crankshaft

15. Check the crankshaft for **distortion** (bending) at the rear connecting rod journal counterweights *before* and *after* installing a power takeoff assembly, marine gear, transmission or power generator. If improperly installed these components can distort the crankshaft and cause a crankshaft malfunction. Overtightened drive belts can also cause crankshaft distortion. See Section 15.1 for recommended belt tension.

    NOTICE: While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel Corporation cannot be responsible for system damage caused by engine–to–driven component interference and/or distortion. Consequently, the engine crankshaft end play check and crankshaft distortion check are **musts**.

    Check the crankshaft distortion as follows:

    a. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the *six o'clock* position.

    b. Center punch a hole in the inside face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gage.

    c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight (Fig. 12).

    d. Set the dial indicator at zero, then rotate the *crankshaft approximately 90° in both directions.* Do not allow the gage to contact the connecting rod caps or bolts. Note and record the dial indicator readings at the *3, 6 and 9 o'clock crankshaft counterweight* positions. The maximum allowable variationis .0045" total indicator reading. Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings.

    e. If the reading on the gage exceeds .0045", check the power takeoff assembly, transmission, marine gear or power generator for improper installation and realign, as necessary.

16. Affix a new gasket to the oil pan flange and install the oil pan.

17. Use a chain hoist and sling attached to the lifting bracket at each end of the engine and remove the engine from the overhaul stand.

18. Install all of the accessories that were removed.

19. After the engine has been completely reassembled, refer to the *Lubrication Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

20. Close all of the drains and fill the cooling system.

21. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the *run–in* schedule (Section 13.2.1).

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the lower front cover on In–line and 6V–53 engines (Fig. 1). The seal is pressed into the front cover on early 8V–53 engines; effective with engine 8D–149, the seal is pressed into the outboard bearing support.

A single–lip oil seal is used at the rear end of the crankshaft of most industrial engines. A double–lip oil seal is used in engines where there is oil on both sides of the oil seal; the lips of the seal face in opposite directions. The rear oil seal is pressed into the flywheel housing (Fig. 2).

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the engine front cover (Section 1.3.5), outboard bearing support or the flywheel housing (Section 1.5) and remove the oil seals as follows:

1. Support the forward face of the front cover, or the outboard bearing support, on two wood blocks next to the oil seal bore. Then, press or drive the oil seal out of the front cover or the outboard bearing support. Discard the oil seal.

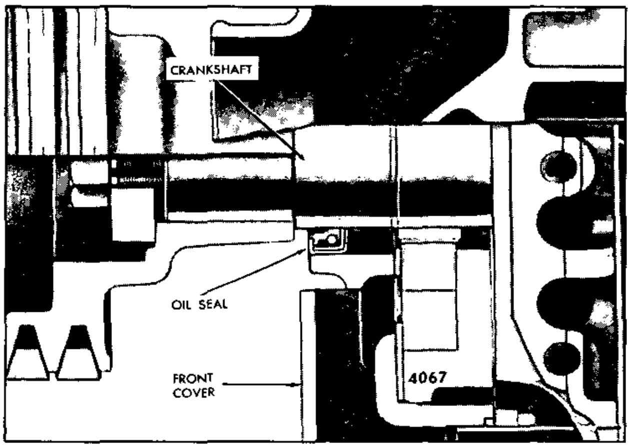


Fig. 1 – Crankshaft Front Oil Seal

2. Support the forward face of the flywheel housing on In–line or 6V–53 engines and the rear face of the flywheel housing on 8V–53 engines on two wood blocks next to the oil seal bore. Then, press or drive the oil seal out of the housing. Discard the oil seal.

3. Clean the oil seal bore in the front cover, outboard bearing support or flywheel housing thoroughly before installing a new oil seal.y

When necessary, an oil seal may be removed without removing the front cover, outboard bearing support or flywheel housing. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars.

Inspection

Inspect the front and rear end of the crankshaft and the crankshaft front end oil seal sleeve (8V–53 engines) for wear due to the rubbing action of the oil seal, dirt build–up or fretting caused by action of the flywheel.

The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection* in Section 1.3.

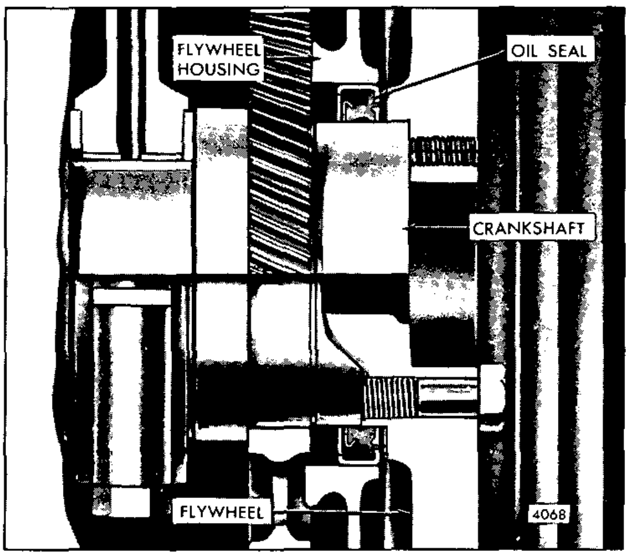


Fig. 2 – Crankshaft Rear Oil Seal
(In–line and 6V–53 Engines)

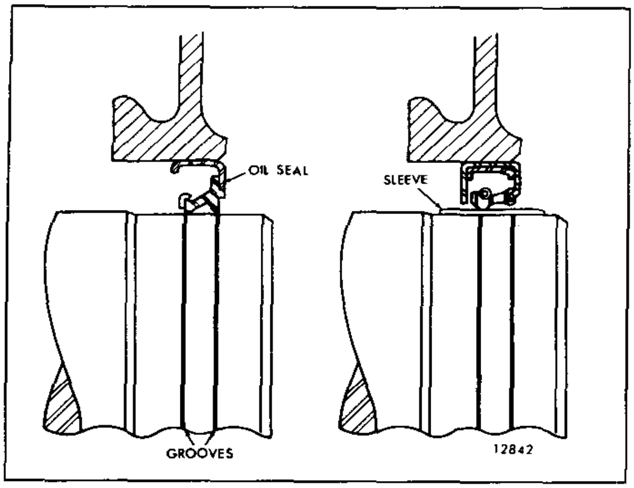


Fig. 3 – Use of Rear Oil Seal Sleeve on Grooved Crankshaft (In–line and 6V–53 Engines)

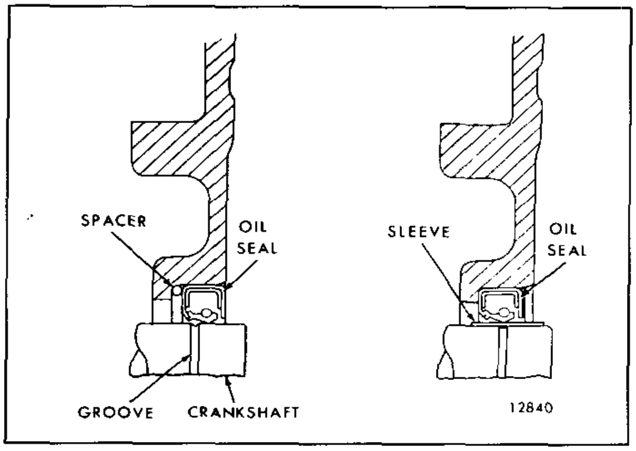


Fig. 4 – Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft (8V–53 Engines)

On In–line or 6V–53 engines, if the crankshaft cannot be cleaned up satisfactorily, the oil seal may be pressed into the flywheel housing or the front cover 1/8" from its original position.

On 8V–53 engines, if the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer may be installed between the counterbore in the flywheel housing and the oil seal (Fig. 4). The spacer changes the relative position of the seal and establishes a new contact surface. However, the spacer cannot be used with a double–lip type seal since the grooves worn in the crankshaft are too close together to permit repositioning of the seal.

If excessive wear or grooving is present, install an oil seal sleeve which provides a replaceable wear surface for the lip–type oil seal (Figs. 3, 4 and 5). The oil seal sleeve may be used with either the single–lip or double–lip type oil seal, and can also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

Install the rear oil seal sleeve (Figs. 3 and 4) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.
2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.
3. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer J 21277 (In–line or 6V–53 engines) or installer J 4194–01 (8V–53 engines).
4. Wipe off any excess sealant.
5. Coat the outside diameter of the sleeve with engine oil.

Install the front oil seal sleeve (Fig. 5) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.
2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.
3. Position the sleeve on the crankshaft with the radius on the sleeve facing away from the engine.
4. Drive the sleeve squarely on the shaft with front oil seal sleeve installer J 22524 and the crankshaft pulley retaining bolt.
5. Wipe off any excess sealant.
6. Coat the outside diameter of the sleeve with engine oil.

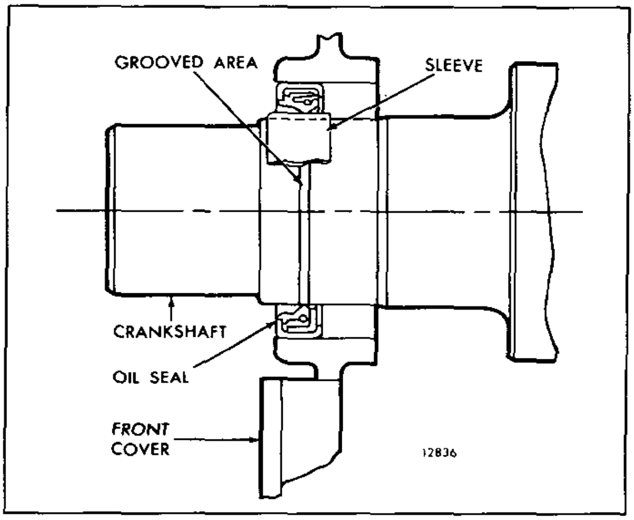


Fig. 5 – Use of Front Oil Seal Sleeve on Grooved Crankshaft

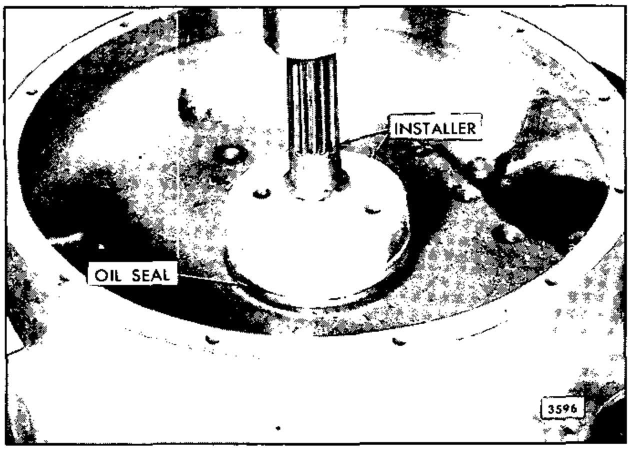


Fig. 6 – Installing Oil Seal in Flywheel Housing

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the end of the crankshaft.

Current oil seals are made of an oil resistant synthetic rubber which is pre–lubricated with a special lubricant. *Do not remove this lubricant.* Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating.

The rear oil seal may have either an open or closed back. Both types are serviced.

Install Crankshaft Front Oil Seal

1. If the oil seal is not pre–coated, apply a non–hardening sealant to the periphery of the metal casing.
2. Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then, position the seal in the cover or outboard bearing support with the lip of the seal pointed toward the inner face of the cover or bearing support.
3. On In–line and 6V–53 engines, use installer J 9783 to press the oil seal into the cover until the seal is flush with the outside face of the cover. On 8V–53 engines, press the oil seal into the outboard bearing support with installer J 22153.
4. Remove any excess sealant.
5. Install the engine front cover (Section 1.3.5) or the outboard bearing support.

Install Crankshaft Rear Oil Seal

A new, unidirectional Teflon rear crankshaft oil seal is being used in all right–hand rotating engines,. To help insure proper installation, the seal part number and the direction of shaft rotation are stamped on the seal case. The new seal is packaged around a special plastic sleeve which protects the Teflon lip of the seal during shipment and storage and functions as an installation tool. It is designed to be placed over the crankshaft end so that the seal can be easily slipped in place without damaging the lip.

NOTICE: Do not lubricate a Teflon seal lip or the O.D. of the crankshaft wear sleeve before seal installation. Teflon lip oil seals must be installed dry. This is to allow transfer of the Teflon to the wear sleeve surface for proper sealing.

1. Support the inner face of the flywheel housing in an arbor press or on a flat surface.
2. If the new seal is not pre–coated, apply a non–hardening sealant to the periphery of the metal casing. Then, position the seal with the lip pointed toward the inner face of the housing.
3. Coat the lip of a silcon oil seal lightly with engine oil (single–lip seal) or vegetable shortening (double–lip seal). Do not scratch or nick the sealing edge of the oil seal.
4. On In–line and 6V–53 engines, use installer J 9479 to press the oil seal into the flywheel housing until the seal is flush with the outside face of the housing (Fig. 6).

   If the flywheel housing was not removed from the engine, place oil seal expander J 9769 (standard size seal) or J 21278–01 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the expander and on the crankshaft. Next, thread the guide studs J 9479–2 into the crankshaft. Now drive the seal into the flywheel housing with installer J 9479–1 until it is flush with the face of the housing.
5. On 8V–53 engines, use installer J 9727 and handle J 3154–1 to press the oil seal in the flywheel housing bore until it seats in the bottom of the counterbore. If the flywheel housing was not removed from the engine, place oil seal expander J 22425 against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 9727 and handle J 3154–1.
6. Remove any excess sealant from the flywheel housing and the seal.

   NOTICE: If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place in the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.
7. Install the flywheel housing as outlined in Section 1.5.

CRANKSHAFT MAIN BEARINGS

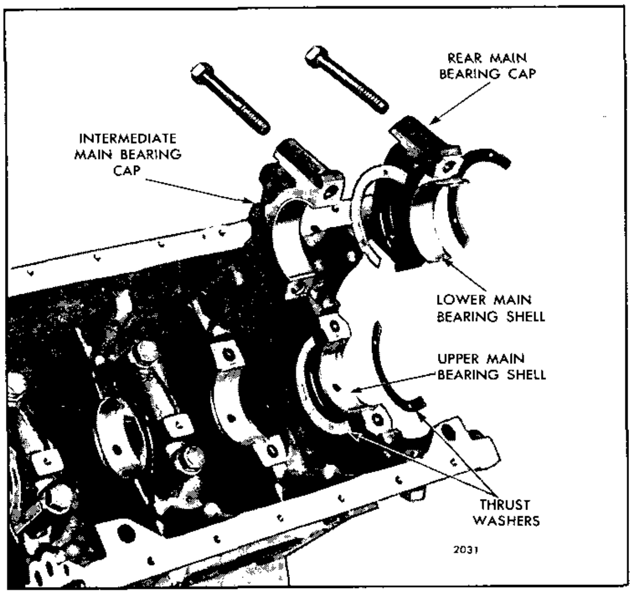


Fig. 1 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers — In-line Engines

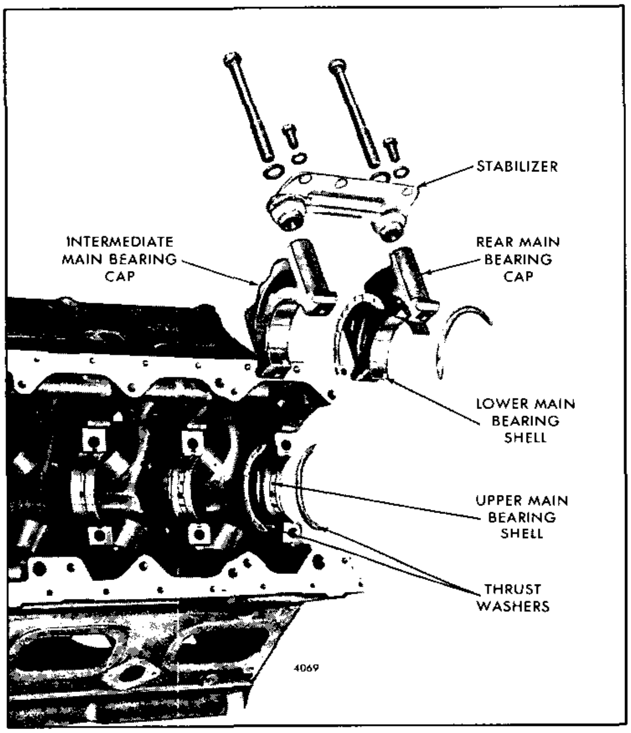


Fig. 2 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers — V-Type Engines

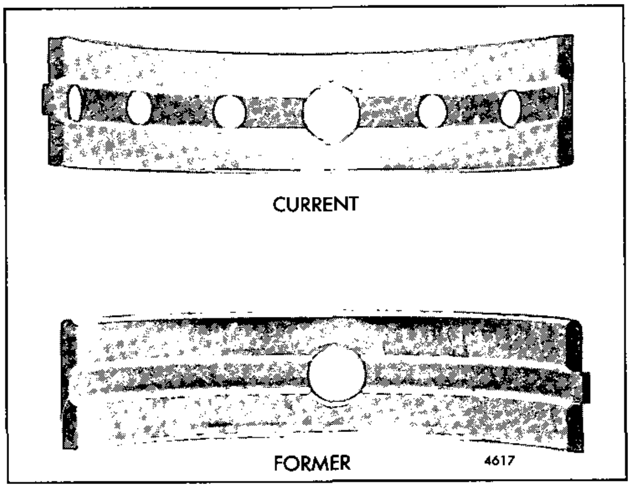


Fig. 3 - Old and New Upper Main Bearing Shells (V-Type Engines)

The crankshaft main bearings shells are precision made and are replaceable without machining (Figs. 1 and 2). They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The upper and lower bearing shells are located in the respective block and bearing cap by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

On In-line and early V-type engines, a 7/16" oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

On 6V marine engines effective with engine serial number 6D-11074 and all other 6V and 8V engines effective with serial numbers 6D-17960 and 8D-4611, an upper main bearing shell which has six 1/4" holes and one 7/16" hole (Fig. 3) is used. The additional holes in the upper main bearing shells improve piston cooling by allowing more oil, under pressure, to flow to the drilled passages in the crankshaft. On the 8V engines, a new high capacity oil pump is used in combination with the seven hole bearing shells.

The single hole and the seven hole upper main bearings are not interchangeable. If the seven hole upper main bearing shells are used on an early engine, the current lower engine front cover (Section 1.3.5), lubricating oil distribution system (Section 4.1) and revised cast iron oil pan (Section 4.7) must be used together. *The single hole and*

seven hole upper main bearing shells must never be mixed in an engine.

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

On Brazil built engines the upper main bearing shell is slotted and the lower shell has grooved sides for continuous piston lubrication.

Thrust washers on each side of the rear main bearing, absorb the crankshaft thrust (Figs. 1 and 2). The lower halves of the two–piece washers are doweled to the bearing cap; the upper halves are not doweled.

All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.
2. Remove the oil pump and the oil inlet pipe and screen assembly. *If shims are used between the oil pump (8V engine) and the main bearing caps, save the shims so that they may be reinstalled in exactly the same location.*
3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection.* Reinstall each bearing shell and bearing cap before removing another bearing cap:
    a. To remove all except the rear main bearing shell, insert a 1/4" x 3/4" bolt with a 1/2" diameter and 1/16" thick head (made from a standard bolt) into the crankshaft journal oil hole. Then, revolve the shaft to the right (clockwise) and roll the bearing shell out of position (Fig. 4). The head of the bolt must not extend beyond the outside diameter of the bearing shell.

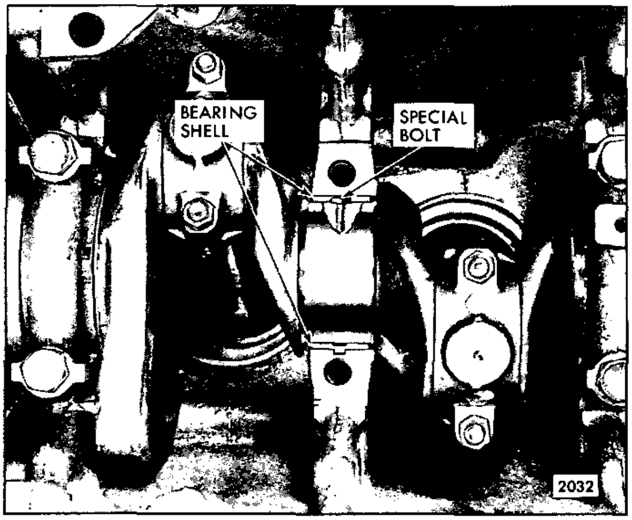


Fig. 4 – Removing Upper Main Bearing Shell (Except Rear Main)

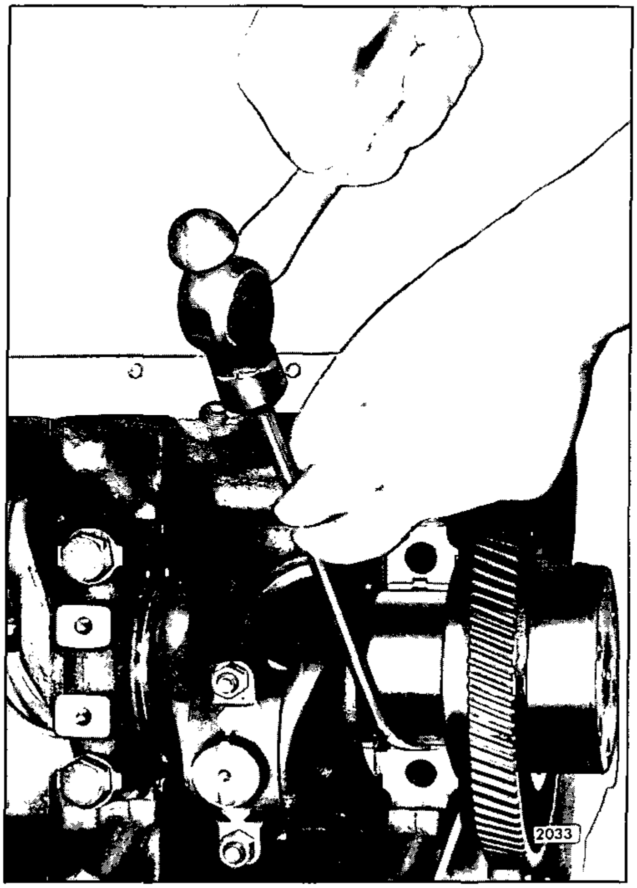


Fig. 5 – Removing Upper Rear Main Bearing Shell

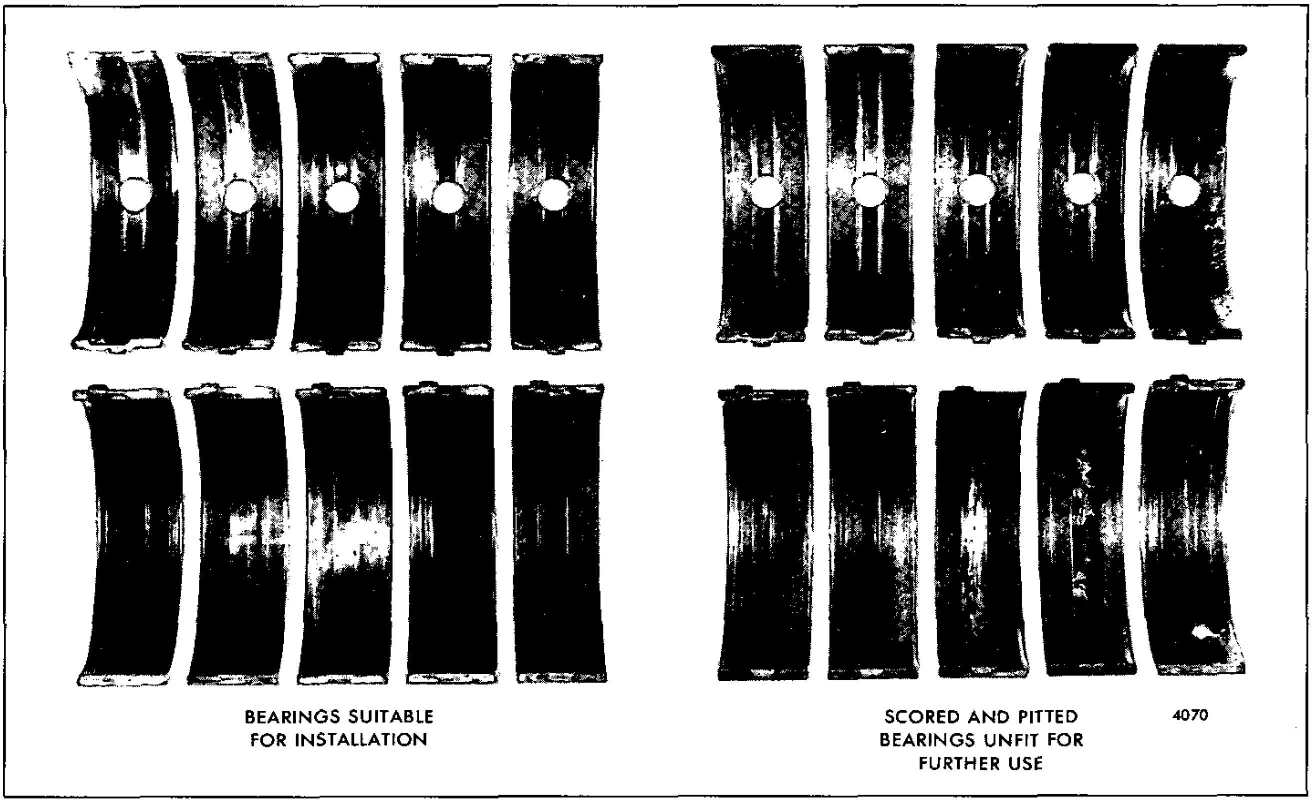


Fig. 6 – Comparison of Main Bearing Shells

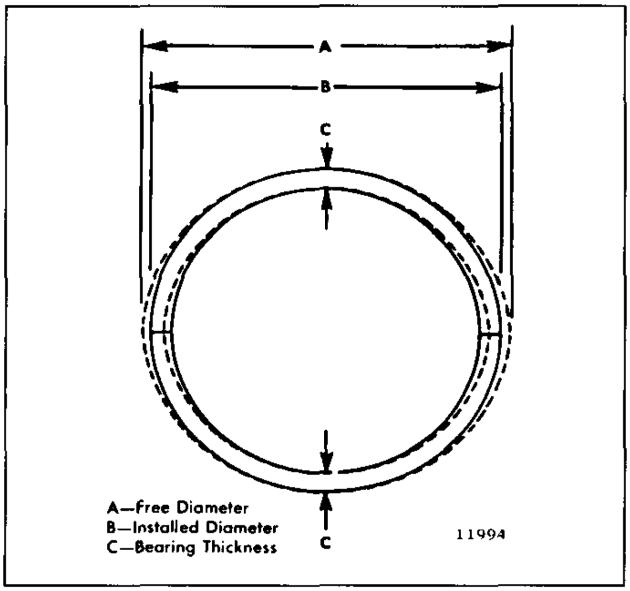


Fig. 7 – Main Bearing Measurements

b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out (Fig. 5).

c. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them, if necessary. Also, check the oil bypass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 6). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point "C", 90° from the parting line (Figs. 7 and 8). Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is .1230" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (In–line engine) or .1240" to .1245" (V engine). Refer to Table 1.

Bearing Size	Bearing Thickness	Minimum Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
V-Type Engine		
Standard	.1240"/.1245"	.1230"
.002" Undersize	.1250"/.1255"	.1240"
.010" Undersize	.1290"/.1295"	.1280"
.020" Undersize	.1340"/.1345"	.1330"
.030" Undersize	.1390"/.1395"	.1380"

TABLE 1

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .001" larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This *crush* assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0060", all of the bearing shells must be discarded and replaced. This clearance is .0010" to .0040" with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Section 1.3 under *Crankshaft Inspection* for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3. Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft. Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Oversize O.D. main bearing shells are also available in .010" and .020" oversize to salvage engine blocks which have experienced block bore wear or damage. The oversize bearing sets may be installed after the block bores have been line–bored to the oversized diameter (Section 1.0 Shop Notes).

Do not mix main bearing shell kits on an engine. Use all oversize or all undersize bearing shells of the same size or use all standard main bearing shell kits.

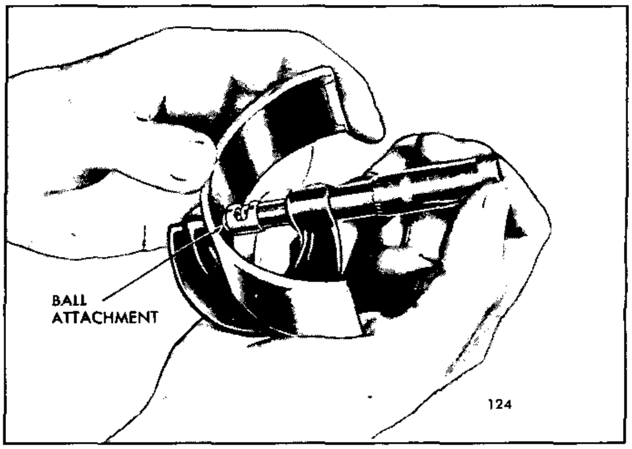


Fig. 8 – Measuring Thickness of Bearing Shell

Inspect the crankshaft thrust washers (Fig. 9). If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to *Install Crankshaft* in Section 1.3. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190″ to .1220″ thick. Thrust washers are available in .005″ and .010″ oversize.

The discovery of a crack in the rear main bearing cap of a 6V naturally aspirated or turbocharged engine does not automatically mean that the cap should be scrapped. The cap may be reused if the crack occurs on the bearing shell side of the dowel pin hole (Item 1 – Fig. 10). Fig. 10 shows the types of cracks which may be encountered on the 6V–53 rear main bearing cap. The reusability of the cap is defined as follows:

1. Cap *can* be reused. Crack occurs on the bearing shell side of the dowel pin hole.
2. Cap *cannot* be reused. Crack occurs on both sides of the dowel pin hole, extending toward the bearing shell area and the cap bolt hole.
3. Cap *cannot* be reused. Crack occurs at a location other than the dowel pin hole.

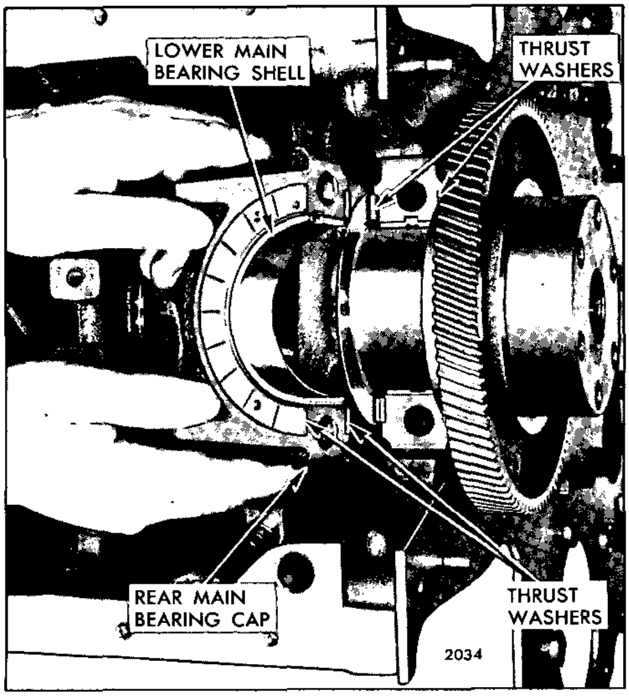


Fig. 9 – Crankshaft Thrust Washers in Place

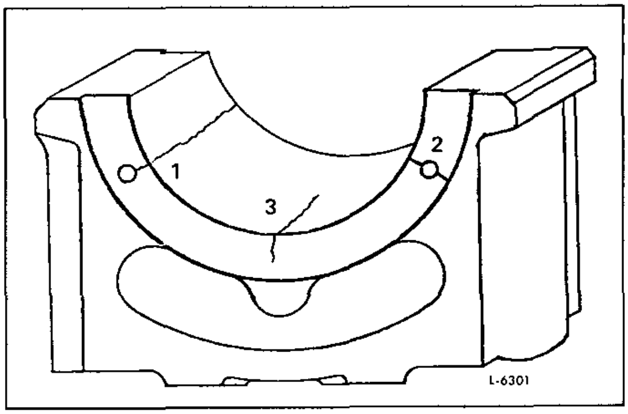


Fig. 10 – 6V Rear Main Bearing Cap Cracks

A pre–finished rear main bearing cap with machined thrust washer surface is available as a service part. After the bearing cap is replaced, the block must be line–bored to insure proper alignment (see Section 1.0 Shop Notes).

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then, apply clean engine oil 360° around each crankshaft bearing journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

- *Upper and lower bearing shells are serviced only in sets. Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.*

Do not mix one hole and seven hole upper main bearing shells in a V–type engine. If the current seven hole bearing shells are installed in an early engine, the current oil pump must be included, otherwise low oil pressure will result.

The upper and lower main bearing shells are not alike; the upper bearing shell is grooved and drilled for lubrication — the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.
2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

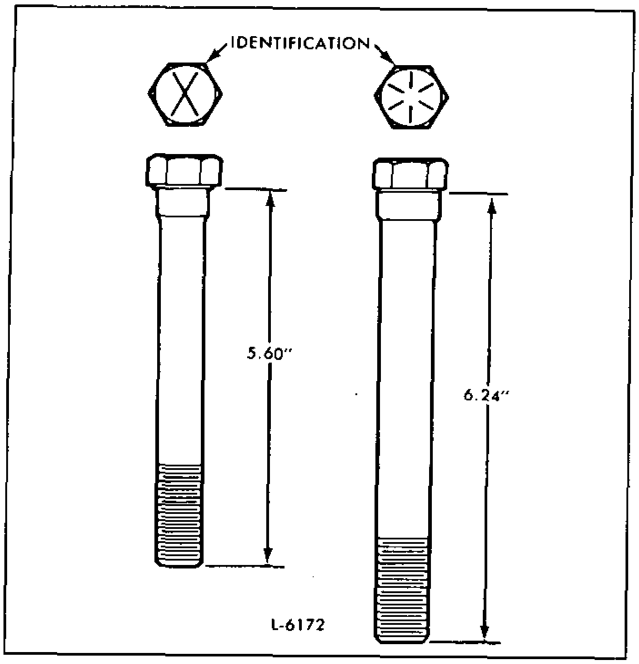


Fig. 11 – Identification of Stabilizer Bolts

3. Assemble the crankshaft thrust washers before installing the rear main bearing cap (Fig. 9). Clean both halves of each thrust washer carefully and remove any burrs from the washer seats — the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then, assemble the lower halves over the dowel pins in the bearing cap. The main bearing caps are bored in position and stamped 1, 2, 3, etc. They must be installed in their *original* positions with the marked side of each cap facing the same side of the cylinder block that carried the engine serial number.

Bearing cap stabilizers are used at all 6V–53 engine main bearing cap positions. However, effective with engine serial number 6D–183126 the stabilizers were removed from the two front main bearing cap positions for the 6V naturally aspirated engines only.

Shorter bolts (9/16"–12 x 5.60") are now used at these two front main bearing cap positions that do not have the stabilizers. The longer 9/16"–12 x 6.24" bolt continues to be used with the stabilizers for the No. 3 and No. 4 main bearing caps. Refer to Fig. 11 for identification of bolts and Fig. 12 for modifications to the 6.24" bolt and washer.

NOTICE: Do not use the shorter bolt with a stabilizer, as this may result in insufficient bolt thread contact and possible engine damage.

4. Apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and stabilizers (if used) and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly. Tighten all bolts (except the rear main bearing bolts) to 120–130 lb–ft (163–177 N·m) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Tighten the rear main bearing bolts to 40–50 lb–ft (54–68 N·m) torque. Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Retorque all bearing bolts to 120–130 lb–ft (163–177 N·m). On a V–type engine, tighten the 7/16"–14 stabilizer bolts to 46–50 lb–ft (62–68 N·m) torque. If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

5. Check the crankshaft end play as outlined under *Install Crankshaft* in Section 1.3.

6. Install the lubricating oil pump and the oil inlet pipe assembly. If shims were used between the pump (8V engine) and the bearing caps, install them in their *original* positions.

7. Install the oil pan, using a new gasket.

8. Fill the crankcase to the proper level on the dipstick with *heavy–duty* lubricating oil of the recommended grade and viscosity (refer to *Lubrication Specifications* in Section 13.3).

9. After installing new bearing shells, operate the engine on a *run–in* schedule as outlined in Section 13.2.1.

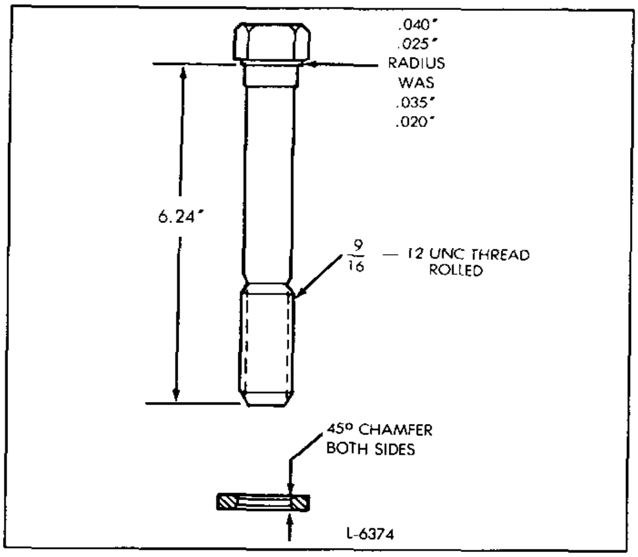


Fig. 12 – Modified 6V Main Bearing Cap Bolt and Washer

ENGINE FRONT COVER (Lower)

In–line and 6V Engines

The engine lower front cover is mounted against the cylinder block at the lower front end of the engine (Figs. 1 and 2). It serves as a housing for the crankshaft front oil seal, the lubricating oil pump, the oil pressure regulator valve and the oil cooler by–pass valve. The clean–out openings in the periphery of the current cover incorporate tapped holes and 1/2"–14 threaded plugs.

On all In–line and 6V engines effective with engine serial numbers 2D–13569 (except 2D–13592, 13597, 13622 and 13626), 3D–4295 (except 3D–4373), 4D–6027 and 6D–3858 (6D–3246, model 5063–5200), the oil pressure regulator valve is located on the right–hand side of the engine front cover, as viewed from the front of the engine. Prior to the above engine serial numbers, the oil pressure regulator valve was located on the left–hand side of the front cover just below the oil cooler by pass valve.

Current 6V engines include a regulator valve with a non–replaceable stop swaged in the valve. When it becomes necessary to replace the regulator valve or plug in an early engine, both must be replaced together. Also, when the valve and plug in either side of the engine lower front cover needs to be replaced, the valve and plug in both sides of the cover must be replaced.

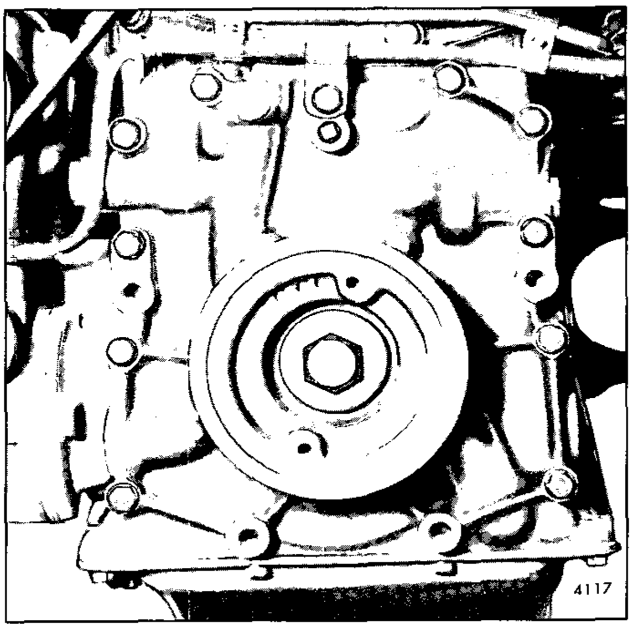


Fig. 1 – Engine Front Cover Mounting (Lower) — In–Line Engine

Remove Engine Front Cover

1. Allow the engine to cool, then drain the oil and remove the oil pan.

2. Remove the crankshaft pulley as outlined in Section 1.3.7.

3. Remove the two bolts and lock washers that secure the lubricating oil pump inlet tube flange or elbow to the engine front cover.

4. Remove the bolts and lock washers that secure the engine front cover to the cylinder block.

5. Strike the cover with a soft hammer to free it from the dowels. Pull the cover straight off the end of the crankshaft.

6. Remove the cover gasket.

7. Inspect the oil seal and lubricating oil pump as outlined in Sections 1.3.2 and 4.1. Also check the oil pressure regulator valve and oil cooler bypass valve as outlined in Sections 4.1.1 and 4.4.

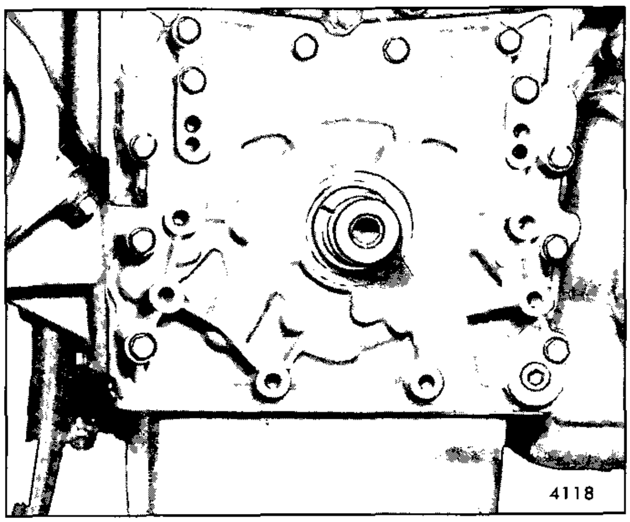


Fig. 2 – Engine Front Cover Mounting (Lower) — 6V–Engine

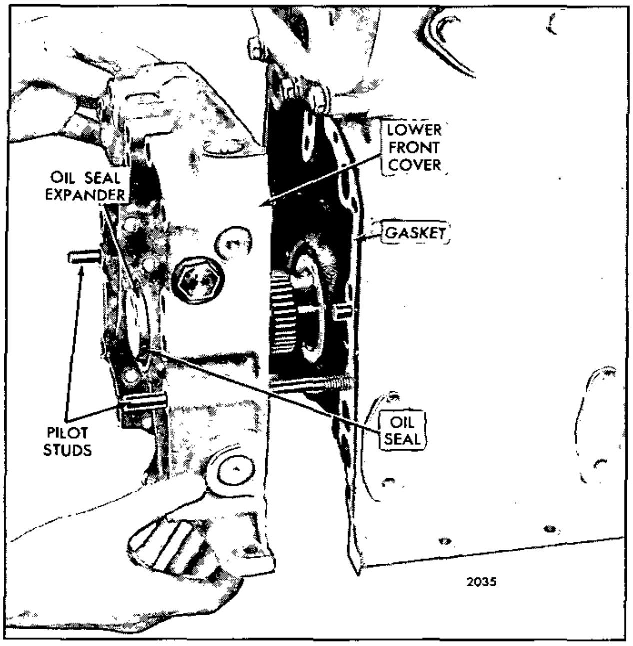


Fig. 3 – Installing Lower Engine Front Cover — In–Line Engine

Install Engine Front Cover

1. Affix a new cover gasket to the cylinder block.
2. Install oil seal expander J 7454 over the front end of the crankshaft.
3. Thread two 3/8"–16 pilot studs approximately 8" long into two diametrically opposite bolt holes in the cylinder block to guide the cover in place (Fig. 3).
4. Apply a light coat of cup grease to the lip of the oil seal. Slide the engine front cover over the oil seal expander and pilot studs as shown in Fig. 3. Push the cover forward until the inner rotor of the oil pump contacts the pump drive gear on the crankshaft. Rotate the crankshaft slightly to align the teeth, then push the cover up against the gasket and block. Do not force the cover.
5. Remove the oil seal expander and pilot studs.
6. Refer to Figs. 1 and 2 and install the 3/8"–16 bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.
7. Affix a new seal ring on the end of the lubricating oil pump inlet tube next to the flange on an In–line engine, or a new gasket to the elbow on a 6V–engine. Attach the flange or elbow to the front cover with bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.
8. Affix a new oil pan gasket to the bottom of the cylinder block, then install and secure the oil pan to the block with bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.
9. Install the crankshaft pulley as outlined in Section 1.3.7.
10. Refer to *Lubricating Oil Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

ENGINE FRONT COVER

8V Engine

The engine front cover serves as a housing for the camshaft front oil seals, the oil pressure regulator valve and the oil cooler by–pass valve. Prior to engine 8D–149, it served as a housing for the crankshaft front oil seal. Effective with engine 8D–149, the crankshaft front oil seal is mounted in the outboard bearing support assembly (Section 1.3.5.1).

Remove Engine Front Cover

1. Remove the crankshaft pulley as outlined in Section 1.3.7.
2. Remove the pulleys from the front ends of the camshafts as outlined in Section 1.7.
3. Remove the engine front cover, including the engine front trunnion and/or outboard bearing support assembly, if used, (Section 1.3.5.1).
4. Remove and discard the cover gaskets.
5. Remove and discard the oil seals.
6. Check the oil pressure regulator and oil cooler by–pass valves as outlined in Section 4.1.1.

Install Engine Front Cover

<u>ON ENGINES</u> Effective with 8D–149:

1. Install the camshaft oil seals, if removed, with installer J 21899.

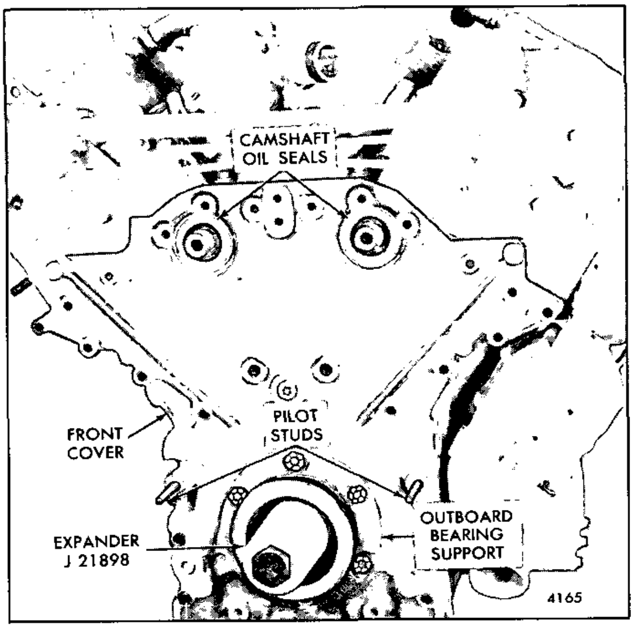


Fig. 4 – Installing Engine Front Cover – 8V–Engine

2. Affix new front cover gaskets to the cylinder block.

3. Install two pilot studs (Fig. 4) into diametrically opposite bolt holes in the cylinder block to guide the engine front cover in place.

4. Slide the front cover over the pilot studs.

5. Remove the pilot studs and install the front cover attaching bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

6. Install the outboard bearing support on the engine front cover as follows:

   a. Install oil seal expander J 21898 (Fig. 4) over the end of the crankshaft. Then apply a light coat of cup grease to the lip of the oil seal and install the outboard bearing support over the oil seal expander and against the engine front cover. Remove the seal expander.

   b. Install the six attaching bolts. Hold the outboard bearing support in a downward position with light hand pressure when tightening the bolts. First snug all the bolts, then tighten them to 75–85 lb–ft (102–115 N·m) torque.

   c. Check the outboard bearing–to–crankshaft clearance with a feeler gage. The clearance must not be less than .0035" or more than .008" with the bearing support in the downward position.

   d. Install the front trunnion, if used.

7. Install the crankshaft front sleeve, if used.

8. Install the crankshaft pulley as outlined in Section 1.3.7.

9. Install the camshaft pulleys as outlined in Section 1.7.

<u>ON ENGINES</u> Prior to 8D–149:

1. Install the camshaft oil seals, if removed, with installer J 21899.

2. Install the crankshaft front oil seal as outlined in Section 1.3.2.

3. Affix new front cover gaskets to the cylinder block.

4. Install the oil seal expander J 21898 over the end of the crankshaft.

5. Install two pilot studs into diametrically opposite bolt holes in the cylinder block.

6. Apply a light coat of cup grease to the lip of the oil seal and guide the front cover over the pilot studs and against the cylinder block.

7. Install the front cover attaching bolts and lock washers and tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

8. Remove the oil seal expander and the pilot studs.

9. Install the crankshaft front sleeve, if used.

10. Install the crankshaft pulley as outlined in Section 1.3.7.

11. Install the camshaft pulleys as outlined in Section 1.7.

CRANKSHAFT OUTBOARD BEARING SUPPORT

8V Engines

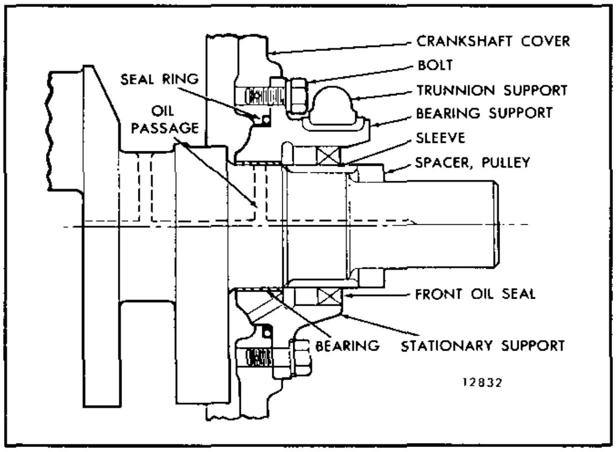


Fig. 1 – Outboard Bearing Support Assembly

The crankshaft outboard bearing support (Fig. 1) houses the crankshaft front outboard bearing (bushing) and the crankshaft front oil seal. The support is a one–piece casting which bolts directly to the engine front cover, providing easy access for removing and installing the oil seal and bearing. A seal ring is used between the bearing support and the engine front cover.

The bearing is pressure lubricated by oil from an internal oil passage in the crankshaft.

The bearing support must be removed when replacement of the bearing or crankshaft oil seal is required.

Remove Outboard Bearing Support

1. Remove the crankshaft pulley (Section 1.3.7).
2. Remove the front trunnion (Fig. 1), if used.
3. Remove the six attaching bolts and detach the bearing support from the engine front cover.
4. Remove and discard the seal ring.

Inspection

Oil leaks are indications of worn or damaged seals.

Inspect the oil seal sleeve for wear due to the rubbing action of the oil seal or dirt build–up. The sleeve must be smooth and clean, otherwise the oil seal lip will be damaged when a new seal is installed.

The oil seal sleeve may be smoothed up with emery cloth and polished with crocus cloth wet with fuel oil. Clean up the circumference of the sleeve without disturbing the concentricity.

Excessive wear or grooving in the crankshaft oil seal sleeve may require the use of a new sleeve (refer to Section 1.3.2).

Inspect the bearing for scoring or excessive wear. The crankshaft to bearing clearance with new parts is .0035" to .0071" and a maximum of .0080" with used parts. The crankshaft journal diameter (new) is 2.8770" to 2.8780".

Install Outboard Bearing Support

1. If the bearing was removed, position a new bearing in the support, with the split line in the bearing toward the bottom of the support (Fig. 2), and press it in until it is flush with the rear face of the support.

   NOTICE: The top of the bearing support is identified by the word "TOP" cast in the front face of the support.

2. Install a new oil seal as outlined in Section 1.3.2.
3. Install a new seal ring on the bearing support.
4. Install the bearing support assembly on the engine front cover as outlined in Section 1.3.5.
5. Install the trunnion support.
6. Install the crankshaft pulley (Section 1.3.7).

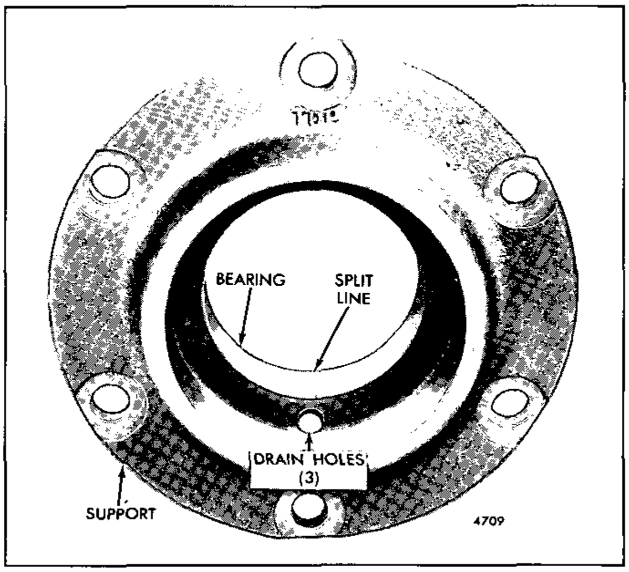


Fig. 2 – Location of Bearing in Support

CRANKSHAFT VIBRATION DAMPER

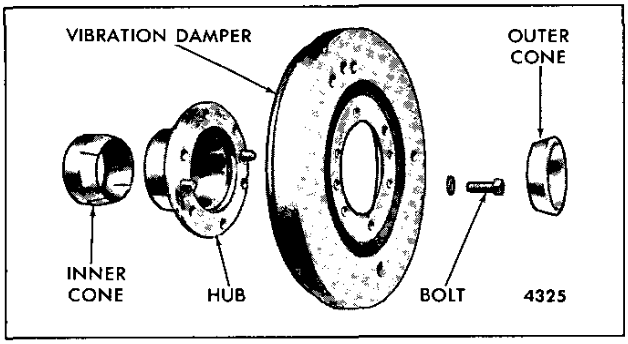


Fig. 1 – Vibration Damper Details and Relative Location of Parts

On certain 8V engines, a viscous type vibration damper is mounted on the front end of the crankshaft to reduce crankshaft stresses to a safe value (Fig. 1). The vibration damper is bolted to a hub which is retained on the front end of the crankshaft.

A viscous type vibration damper consists of an inertia mass (flywheel) enclosed in a fluid–tight outer case but separated therefrom by a thin wall of viscous liquid not responsive to temperature changes. Any movement of the inertia mass, therefore, is resisted by the friction of the fluid, which tends to dampen excessive torsional vibrations in the crankshaft.

The vibration damper must be removed whenever the crankshaft, crankshaft front oil seal or crankshaft front cover is removed.

• Vibration Damper Safety Shields

The need for a vibration damper safety shield is mandatory in certain industrial and marine applications in which the engine operates without a hood or in an open or unprotected area. A properly designed and installed safety shield prevents direct physical contact with the damper during engine operation. It also keeps the damper from "walking off" the crankshaft and causing property damage or injury to personnel working near the engine if the crankshaft pulley bolt should loosen and become detached during engine operation.

Detroit Diesel Corporation does not manufacture, sell, or install vibration damper safety shields as it has no control over the great variety of installations in which DDC engines are applied. Space restrictions in these numerous applications make the supply of a properly designed and shaped vibration damper safety shield the responsibility of the OEM (original equipment manufacturer) or distributor designing and/or manufacturing products in which they apply Detroit Diesel engines. However, DDC believes that the following guidelines should be followed when fabricating or installing shields:

1. Shields should be made form 1/8" to 3/16" perforated steel or heavy steel screen.
2. The perforated or open screen area of the shield should be equal to, or greater than, the total area of both sides of the damper and its circumference.
3. Shields should be no closer than 1/2" from the damper when installed.
4. In all cases, safety shields *must* permit the vibration damper to be well ventilated during engine operation to prevent vibration damper overheating.

NOTICE: Shielded vibration dampers are frequently difficult to inspect visually because of the design of the shield and/or end items in which the engine is installed. As a result, it is important for OEM's and distributors to supply written instructions to users of their products, cautioning them to periodically inspect the viscous vibration damper for evidence of a split seam, bulged cover, leaks, dents, etc. Any such evidence is sufficient cause for replacement because these conditions can prevent vibration dampers from functioning properly and, as a result, cause serious engine damage. *At time of normal major engine overhaul, the damper must be replaced, regardless of condition.*

Remove Vibration Damper

1. Remove the crankshaft pulley retaining bolt and washer.
2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley.
3. Reinstall the pulley retaining bolt in the end of the crankshaft.
4. Attach puller J 24420 to the vibration damper hub, as shown in Fig. 2, with two long bolts threaded into the two 3/8"–24 tapped holes provided in the hub. Pull the damper and hub assembly, together with the outer cone, until the outer cone is loose on the crankshaft.
5. Remove the puller from the damper hub and pull the outer cone off of the crankshaft.

   NOTICE: Pounding with a hammer or prying with other tools must not be resorted to when removing a viscous type damper from the crankshaft. Dents in the damper outer case may render the damper ineffective. *The damper cannot be repaired.*

6. Slide the vibration damper and damper hub as an assembly off of the end of the crankshaft by hand.
7. If necessary, remove the vibration damper inner cone from the crankshaft.

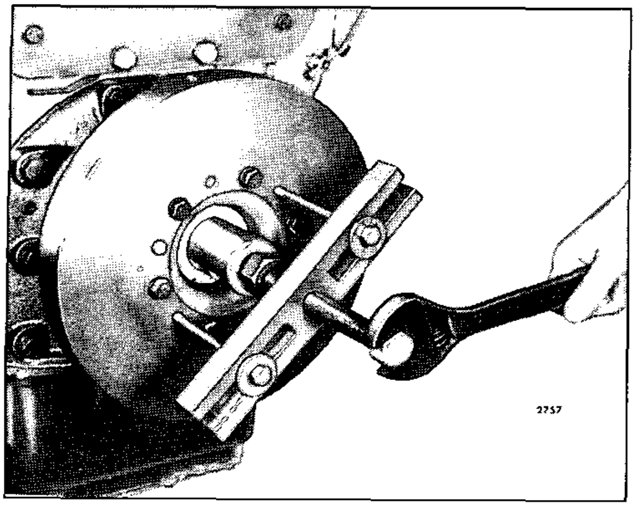


Fig. 2 – Removing Vibration Damper Outer Cone

Inspection

Inspect the damper for dents, nicks, fluid leaks or bulges in the outer casing. Any indications of the above are sufficient cause for replacement of the damper. Due to the close clearances between the damper internal flywheel and the outer casing, dents may render the damper ineffective. Bulges or splits indicate the fluid in the damper has deteriorated and has bulged or forced the casing open at its crimped edges.

Regardless of condition, a viscous type damper must be replaced at the time of normal periodic major engine overhaul.

If damage to the vibration damper is extensive, inspect the crankshaft as outlined in Section 1.3. A loose or defective vibration damper, after extended operation, may result in a cracked crankshaft.

Inspect the damper inner and outer cones, damper hub *and the end of the crankshaft for galling or burrs. Slight* scratches or burrs may be removed with emery cloth. If seriously damaged, replace the parts and refinish the end of the crankshaft. Check the outside diameter of the inner cone for wear at the crankshaft front oil seal contact surface. If worn, replace the oil seal and cone (refer to Section 1.3.2).

A loose engine mount could also damage the vibration damper by allowing the engine to move slightly during operation. Therefore, it is good practice to periodically inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

Install Vibration Damper

All parts on the front of the crankshaft must be positioned without any noticeable interference.

1. *If removed, pilot the damper inner cone over the end of* the crankshaft, through the oil seal and up against the oil slinger, with the tapered end of the cone pointing *toward the front end of the crankshaft.*
2. Slide the damper and hub as an assembly over the end of the crankshaft (with the long end of the hub facing the inner cone) and up against the damper inner cone. *Do not* hit the damper with a hammer to position it on the crankshaft.
3. Slide the damper outer cone over the end of the crankshaft and up against the damper hub, with the tapered end of the cone pointing toward the hub.
4. *Install the pulley on the crankshaft.*
5. Place the washer on the crankshaft end bolt and thread the bolt into the end of the crankshaft.
6. Tighten the crankshaft end bolt as follows:
   a. Tighten the bolt to 180 lb–ft (244 N·m) torque.
   b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.
   c. Tighten the bolt to 300 lb–ft (407 N·m) torque and strike the bolt again.
   d. Retighten the bolt to 300 lb–ft (407 N·m) torque. *Do not hit the crankshaft end bolt after the last tightening of the bolt or the clamping effect will be reduced.*

The damper must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cone will hold the damper rigidly in place.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, *serious engine damage may result if* the vibration damper or pulley is not securely fastened to the crankshaft.

- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away *from the engine as there is a remote* possibility the engine could start.**

CRANKSHAFT PULLEY

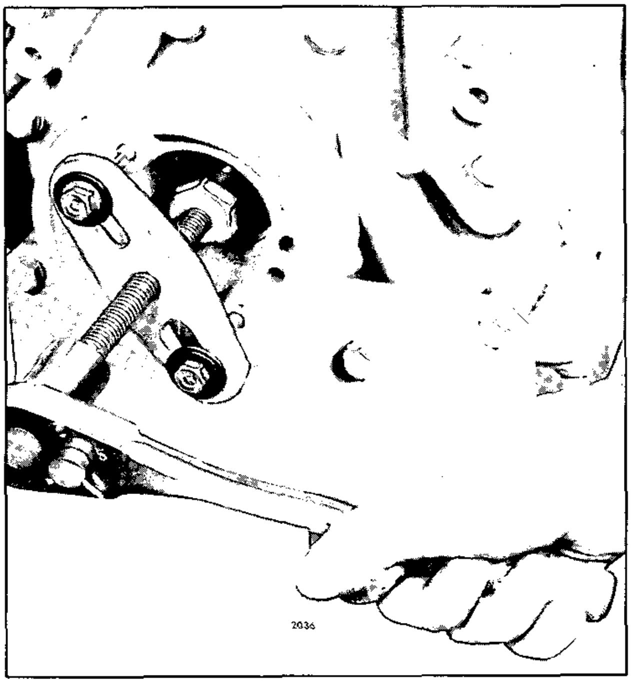


Fig. 1 – Removing Crankshaft Pulley Using Puller J 24420–A

The crankshaft pulley is secured to the front end of the crankshaft by a special washer and a bolt. The engine application determines the type of crankshaft pulley to be used.

The appearance of the rubber bushing (if used) does not determine the condition of a rubber mounted crankshaft pulley. Check for failure of the rubber bushing by locking the crankshaft and applying pressure to the crankshaft pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the rubber bushing.

Remove Crankshaft Pulley

1. Remove the belts from the crankshaft pulley.
2. Remove the crankshaft pulley retaining bolt and special washer.
3. If a rigid type pulley is being removed from an In–line or 6V engine, install the pulley retaining bolt and puller J 24420–A (Fig. 1). Then, force the pulley off the crankshaft by turning the puller center screw in.

On pulleys that do not incorporate two tapped holes in the front face of the pulley, use a two arm universal type puller.

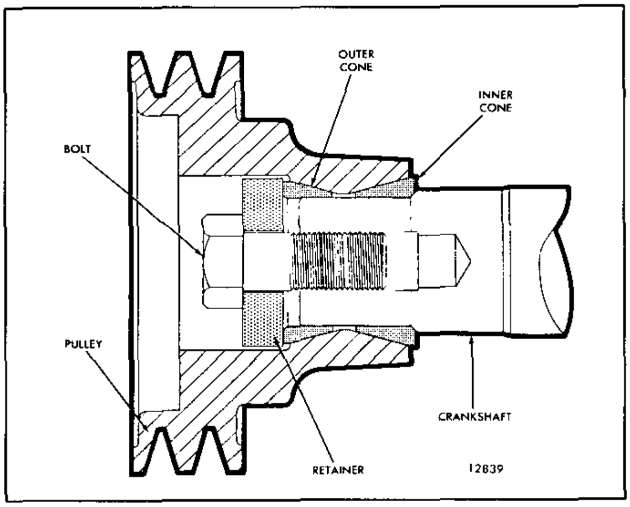


Fig. 2 – Cone Mounted Pulley

If a puller is required to remove a rigid type pulley from an 8V engine, use a universal type puller. Three tapped holes are provided in the pulley to facilitate removal.

4. Remove the outer and inner cones, if used.
5. If a rubber mounted pulley with an internal thread is being removed from an 8V engine, use puller J 5356. To use the tool, screw the 2–1/2"–16 thread into the pulley hub as far as possible with the center screw backed off. Then, force the pulley off the crankshaft by turning the center screw in.

Install Crankshaft Pulley

1. Lubricate the end of the crankshaft with engine oil to facilitate pulley installation.
2. Slide the inner cone (Fig. 2), if used, on the crankshaft.

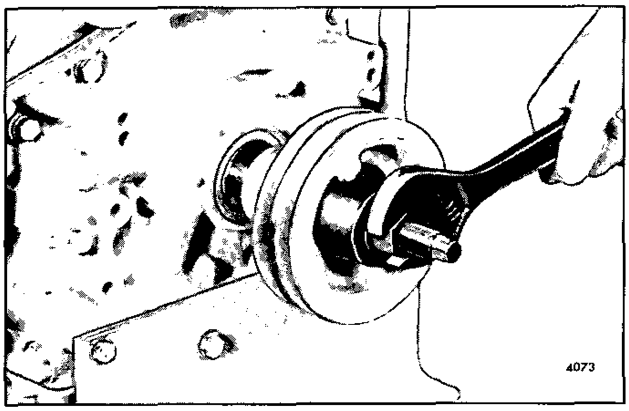


Fig. 3 – Installing Crankshaft Pulley Using Installer J 7773

3. On an 8V engine, install two Woodruff keys (if removed) in the keyways in the front end of the crankshaft.
4. *Start the pulley straight on the end of the crankshaft.*
5. Install a rigid type pulley on an In–line or 6V engine with installer J 7773 (Fig. 3). Then, remove the installer.
6. Slide a rigid type pulley on an 8V engine. If necessary, hold a block of wood against the hub of the pulley and tap the pulley on the crankshaft with a hammer.
7. Slide the outer cone (Fig. 2), if used, on the crankshaft.
8. Place the washer on the crankshaft bolt and thread the bolt into the front end of the crankshaft.
9. On certain 4–53 and 6V engines, a splined crankshaft pulley is used. Place a drive flange washer over the splined end of the crankshaft. Align the splines and tap the pulley on the crankshaft with a plastic hammer. Place another drive flange washer on the bolt and thread it into the end of the crankshaft. Tighten the 3/4″–16 bolt to 290–300 lb–ft (393–407 N·m) torque.
10. On In–line engines with cone mounted pulleys NOT stamped with the letter "A", tighten the 3/4″–16 bolt to 290–300 lb–ft (393–407 N·m) torque.
11. On all In–line and 6V engines with the rigid type pulleys and cone mounted pulleys stamped with the letter "A", tighten the 3/4″–16 bolt to 200–220 lb–ft (271–298 N·m) torque.
12. When pulleys stamped with the letter "U" (in a square box) are used, tighten the 3/4″–16 bolt to 290–310 lb–ft (393–421 N·m) torque.
13. On 8V engines, tighten the 1″–14 crankshaft end bolt as follows:
    a. Tighten the bolt to 180 lb–ft (244 N·m) torque.
    b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.
    c. Retighten the bolt to 300 lb–ft (407 N·m) torque. *Do not hit the crankshaft end bolt after the last tightening of the bolt or the clamping effect will be reduced.*
14. Install and adjust the belts.

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with six self–locking bolts. On an 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true alignment with the clutch or a power take–off driving ring, and the center bore provides for installation of a clutch pilot bearing. The clutch or power take–off driving ring is bolted to the flywheel.

An oil seal ring, which provides an oil tight connection between the crankshaft and the flywheel, is fitted into a groove on flywheels used with hydraulic couplings, clutches or Torqmatic converters.

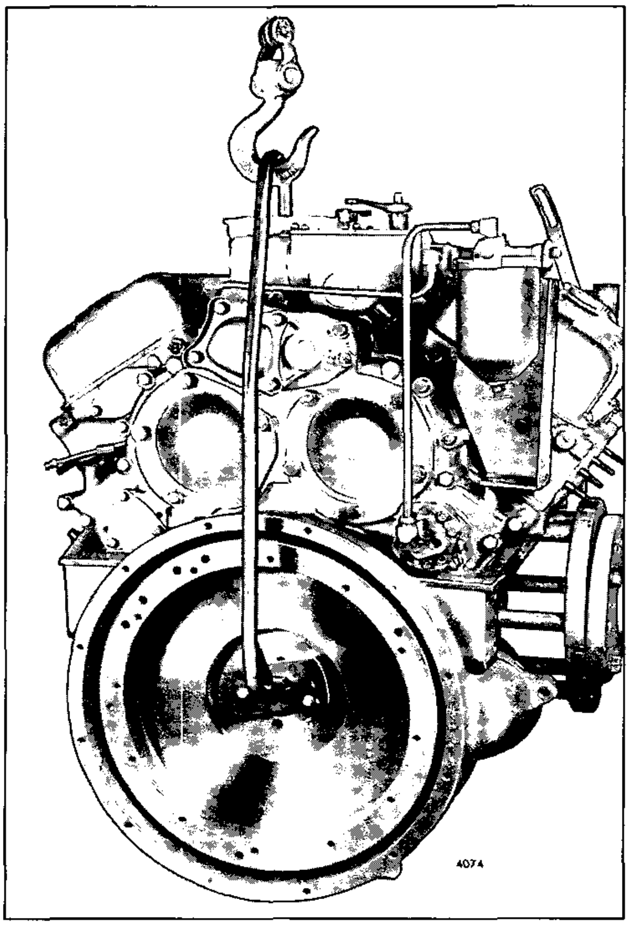


Fig. 1 – Removing Flywheel

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing. On torque converter units, the flywheel is part of the torque converter assembly and is covered in the applicable converter service manual.

Remove Flywheel (Transmission Removed)

1. If a clutch housing is attached to the flywheel housing, remove the flywheel as follows:
   a. Remove the flywheel attaching bolts and the scuff plate.
   b. Lift the flywheel off the end of the crankshaft and out of the clutch housing.
2. If a clutch housing is not used, remove the flywheel as follows:
   a. Remove the flywheel attaching bolts and the scuff plate while holding the flywheel in position by hand, then reinstall one bolt.

CAUTION: When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft, except on 8V engines.

   b. Attach flywheel lifting tool J 6361–01 to the flywheel with two 3/8″–16 bolts of suitable length as shown in Fig. 1 or use tool J 25026.
   c. Attach a chain hoist to the lifting tool.
   d. Remove the remaining flywheel attaching bolt.
   e. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.
   f. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.
   g. Remove the oil seal ring, if used.

Inspection

Check the clutch contact face of the flywheel for scoring, overheating or cracks. If scored, the flywheel may be refaced. However, *do not* remove more than .020″ of metal from the flywheel. Maintain all of the radii when refacing the flywheel.

Replace the ring gear if the gear teeth are excessively worn or damaged.

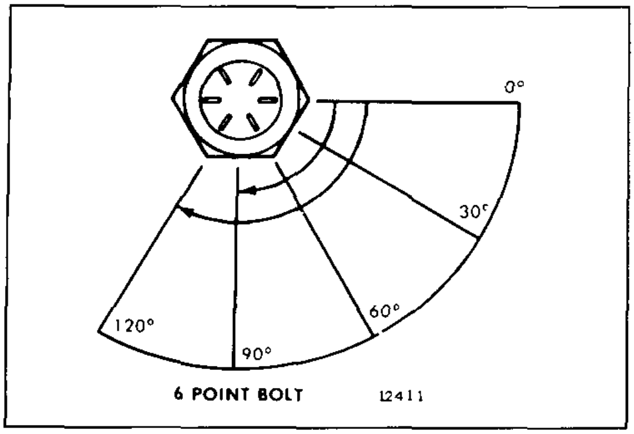


Fig. 2 – Torque–Turn Limits

Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2" from the crankshaft.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to ensure proper metal–to–metal contact and maximum friction, before attaching the flywheel.

New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block which is slightly smaller than the inside diameter of the ring gear.
2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.
3. If a clutch pilot bearing is used, inspect the bearing and replace it, if necessary.

Install Ring Gear

1. Support the flywheel, ring gear side up, on a solid flat surface.
2. Rest the ring gear on a flat **metal surface** and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

   NOTICE: Do not, under any circumstances, heat the gear over 400°F (204°C); excessive heat may destroy the original heat treatment. Heat indicating "crayons", which are placed on the ring gear and melt at a pre–determined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat. Refer to the notice above.

Install Flywheel

1. Install a new oil seal ring, if used.
2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs) or clutch housing. Align the flywheel bolt holes with the crankshaft bolt holes.
3. Install the clutch pilot bearing (if used).
4. Install two bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.
5. Remove the flywheel lifting tool.
6. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

   NOTICE: International Compound No. 2 must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

7. Install the remaining bolts and run them in snug.
8. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.
9. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb–ft (68 N·m) torque.
10. Turn the bolts an additional 90°–120° (Fig. 2) to obtain the required clamping.

NOTICE: Since the *torque–turn method* provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the increased *clamp direction* to prevent underclamping.

11. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .001″ total indicator reading per inch of radius (or .001 mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

On most applications, the clutch pilot bearing is held in place on one side by a shoulder in the flywheel and on the other side by a bearing retainer.

On certain applications, the clutch pilot bearing is held in place on one side by a bearing retainer, placed between the flywheel and the end of the crankshaft, and on the other side by the flywheel bolt scuff plate.

Lubrication

A single–shielded ball type clutch pilot bearing should be packed with an all purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double–sealed clutch ball type pilot bearing is prepacked with grease and requires no further lubrication.

Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the crankshaft, the clutch pilot bearing may be removed as follows:

1. Remove the flywheel attaching bolts and scuff plate while holding the flywheel in position by hand, then reinstall two bolts to hold the flywheel in place.

   When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft, except on an 8V engine.

2. With the clutch pilot bearing remover adaptor J 23907–2 attached to slide hammer J 23907–1, insert the fingers of the adaptor through the pilot bearing and tighten the thumb screw to expand the fingers against the inner race of the bearing.

3. Tap the slide hammer against the shoulder on the shaft and pull the pilot bearing out of the flywheel.

Inspection

Wipe the prepacked double–sealed bearing clean on the outside and inspect it. *Shielded bearings must not be washed;* dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Check the bearing for free rolling by holding the inner race and revolving the outer race *slowly* by hand. Rough spots in the bearing are sufficient cause for rejecting it.

Install Clutch Pilot Bearing

1. Lubricate the outside diameter of the bearing with clean engine oil.

2. Start the pilot bearing straight into the bore of the flywheel, with the numbered side of the bearing facing away from the crankshaft.

3. Place bearing installer J 3154–04, with suitable adaptor plates, against the pilot bearing. Then drive the bearing straight into and against the shoulder in the flywheel.

4. Install the flywheel as outlined in Section 1.4.

ENGINE DRIVE SHAFT FLEXIBLE COUPLING

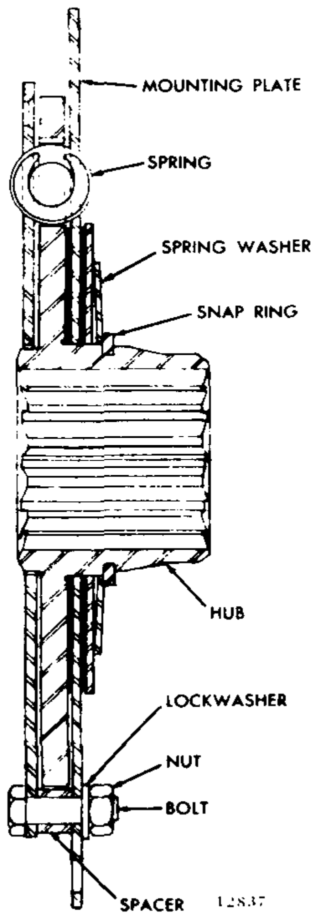


Fig. 1 – Engine Drive Shaft Flexible Coupling

The engine drive shaft flexible coupling (Fig. 1) is of the spring–loaded type having a splined hub to match with the splines on the transmission drive line shaft used on certain applications. The coupling, bolted to the engine flywheel, serves as a drive and also dampens out torque fluctuations between the engine and the transmission.

Remove Coupling (Transmission Removed)

Remove the eight 3/8"–16 x 7/8" bolts which attach the coupling to the flywheel and remove the coupling.

Inspection

Wash the coupling in clean fuel oil and dry it with compressed air. Check for broken or worn springs.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Springs may be replaced by removing the six bolts, lock washers, nuts and spacers holding the two plates together and removing the smaller plate. After replacing the springs, bolt the plates together and tighten the nuts to 25–30 lb–ft (34–41 N·m) torque.

Examine the hub splines for wear and check the flatness of the mounting plate (the plate which bolts to the flywheel). Since the plates, spacers and hubs are manufactured in matched sets, worn hubs or plates cannot be replaced individually, but must be replaced by a complete flexible coupling assembly.

Install Coupling

Align the bolt holes in the coupling with the tapped holes in the flywheel. Since one bolt hole is offset, the coupling can be attached in only one position. Install the eight 3/8"–16 x 7/8" bolts and tighten them securely.

FLYWHEEL HOUSING

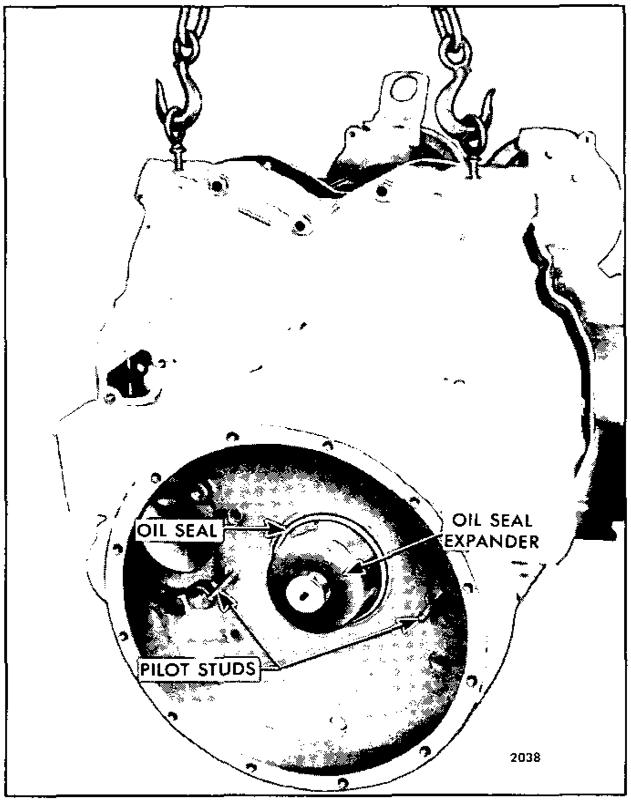


Fig. 1 – Removing or Installing Flywheel Housing

The flywheel housing is a one–piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the transmission.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Section 1.3.2).

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined in Section 1.1.
2. Remove the starting motor from the flywheel housing or the clutch housing.
3. Remove the flywheel.
4. Remove the oil pan.
5. Remove the clutch housing, if used.

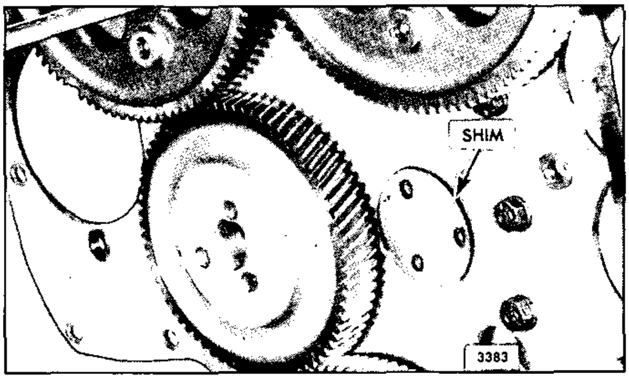


Fig. 2 – Location of Shim

6. Remove the fuel pump, if it is mounted on the flywheel housing.
7. Remove the blower drive cover on 6V and 8V engines, the blower drive shaft retainer ring and the blower drive shaft on the 6V engine.
8. Remove the governor and blower drive support (6V engine).
9. Remove all of the bolts from the flywheel housing. Also remove the blower–to–flywheel housing bolts on the 2–53 or 3–53 engines.

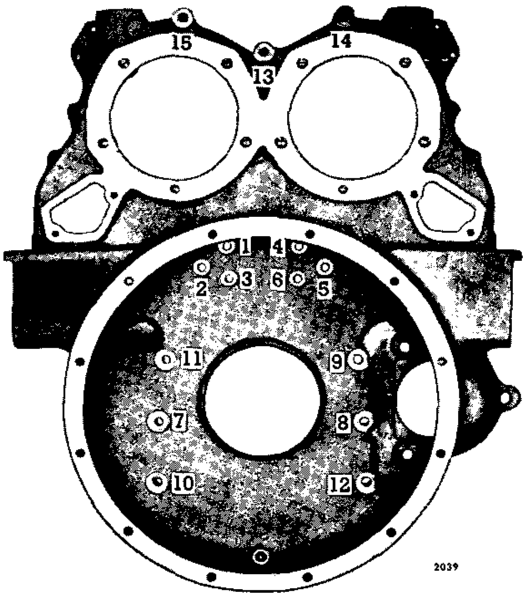
   When removing the flywheel housing bolts, note the location of the various size bolts, lock washers, flat washers and copper washers so they may be reinstalled in their proper location.
10. To guide the flywheel housing until it clears the end of the crankshaft, thread two pilot studs J 7540 into the cylinder block (Fig. 1).
11. Thread eyebolts into the tapped holes in the pads (if provided) on the top or sides of the flywheel housing and attach a chain hoist with a suitable sling to the eyebolts. Then strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.

Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise, runout of the pilot and face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in Section 1.3.2.



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x7/8"	1-2-4-5
3/8"-16x2 1/2"	7-8-9-10-11-12
3/8"-24x3 9/16"	13-14-15

Fig. 3 – Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)—In–Line Engine

Install Flywheel Housing

1. Lubricate the gear train teeth with clean engine oil.

2. Affix a new flywheel housing gasket to the rear face of the cylinder block rear end plate. The V–type engines employ two gaskets (one large and one small). Affix the small (7/8" dia.) gasket near the top of the end plate.

3. *If the flywheel housing has an integral cast hub,* install a flywheel housing–to–end plate shim (.015" thick). Use grease to hold the shim to the cylinder block rear end plate (Fig. 2).

4. Coat the lip of the crankshaft oil seal lightly with engine oil (single–lip seal) or vegetable shortening *(double–lip seal). Do not scratch or nick the sealing* edge of the oil seal.

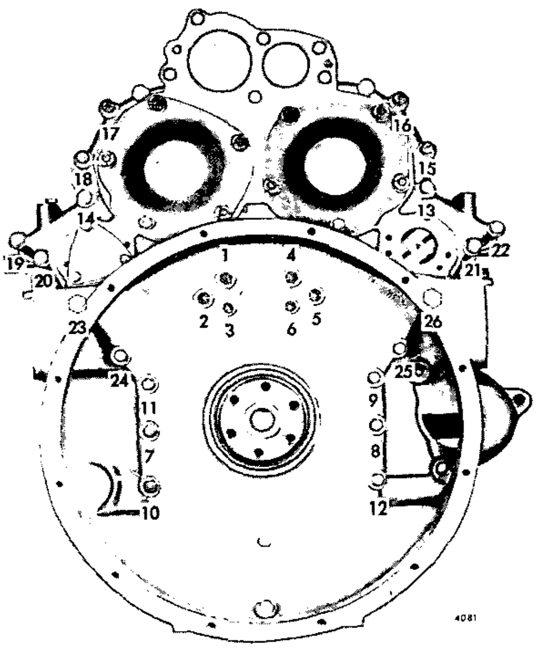
- **NOTICE:** Do not lubricate a Teflon seal lip or the O.D. of the crankshaft wear sleeve before seal installation. Teflon lip seals must be installed dry. This is to allow the transfer of the *Teflon to the crankshaft or wear sleeve for* proper sealing.

5. Thread two pilot studs J 7540 into the cylinder block to guide the housing in place (Fig. 1). On In–line and 6V engines, to pilot the oil seal on the crankshaft successfully, use oil seal expander J 9769 (standard size seal) or J 21278–01 (oversize seal) on the end of the crankshaft. On 8V engines, use oil seal expander J 22425.

6. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket(s). Remove the oil seal expander.

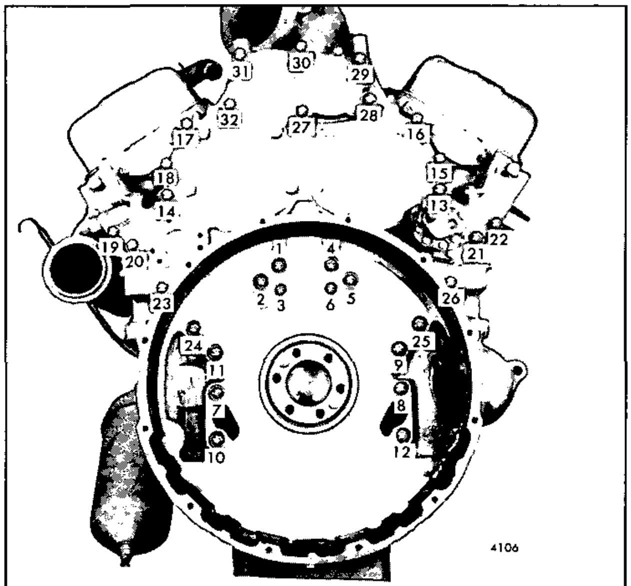
7. Install all of the flywheel housing bolts, lock washers, flat washers and copper washers in their proper location, finger tight. Remove the pilot studs.

   If the engine is equipped with a clutch housing, do not install the six bolts numbered 7 through 12 (Fig. 3) until the clutch housing is installed.



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x2 1/2"	1-2-4-5-7-8-9-10-11-12-24-25
3/8"-16x2 3/4"	23-26
3/8"-16x3 3/4"	13-14-19-20-21-22
3/8"-24x3 1/4"	15-16
3/8"-24x3 1/2"	17-18

Fig. 4 – Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)—6V Engine



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x2 1/2"	1-2-4-5
3/8"-16x2 3/4"	7-8-9-10-11-12-24-25
3/8"-16x3 1/2"	13-14
3/8"-16x3 3/4"	27-28-29-32
3/8"-16x4" Cad	19-20-21-22
3/8"-24x3 1/4"	15-16
3/8"-24x3 1/2"	17-18
3/8"-16x6 3/4"	23-26

Fig. 5 – Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1)—8V Engine

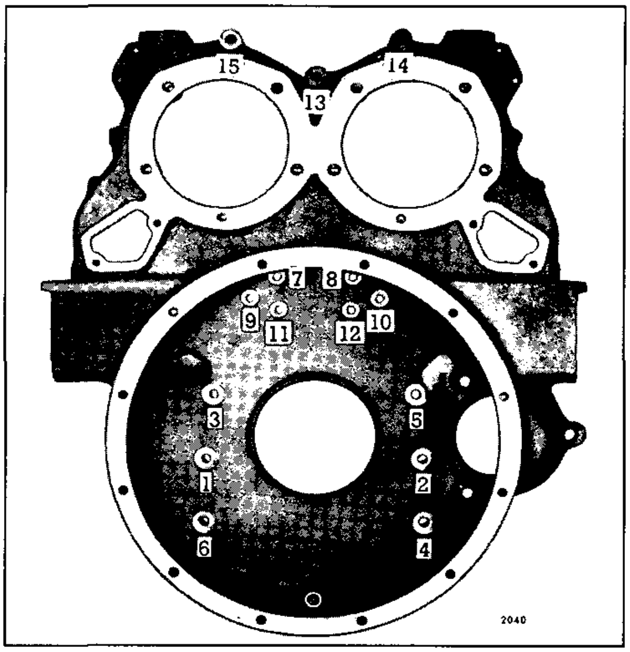


Fig. 6 – Flywheel Housing Bolt Tightening Sequence (Operation 2)—In–Line Engine

8. On an In–line right–hand rotation engine, start at No. 1 (No. 4 on left–hand rotation engine) and draw the bolts up snug in the sequence shown in Fig. 3. On V engines, start at No. 4 on a right–hand rotation engine (No. 1 on a left–hand rotation engine) and draw the bolts up snug in the sequence shown in Figs. 4 and 5.

   NOTICE: On an 8V engine, when tightening the idler gear hub bolts, turn the engine crankshaft to prevent any bind or brinelling of the idler gear bearing. The crankshaft must be rotated for the flywheel housing bell bolt tightening also.

9. Refer to Fig. 6 for the final bolt tightening sequence on an In–line engine. Then start at No. 1 and tighten the bolts to the specified torque.

   a. Tighten the 5/16"–18 bolts (numbers 11 and 12) to 19–23 lb–ft (26–31 N·m) torque and the 3/8"–16 bolts (numbers 7 through 10) to 40–45 lb–ft (54–61 N·m) torque. Tighten the remaining 3/8"–16 and 3/8"–24 bolts to 25–30 lb–ft (34–41 N·m) torque.

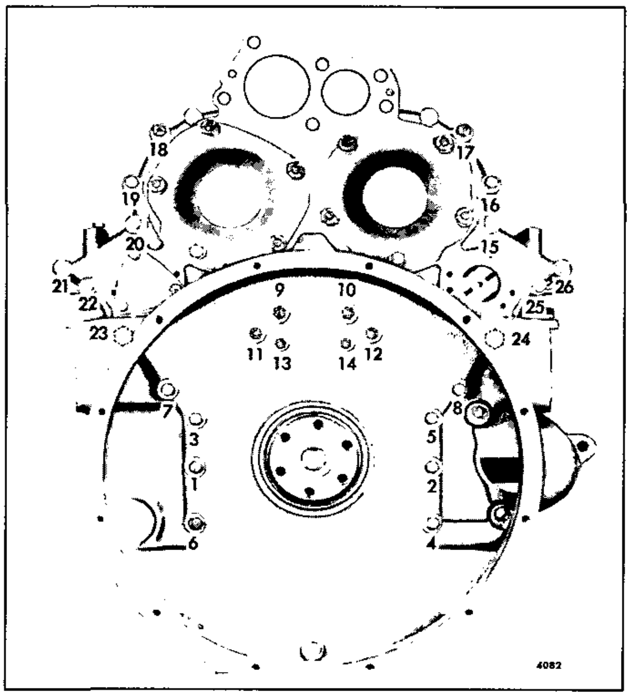


Fig. 7 – Flywheel Housing Bolt Tightening Sequence (Operation 2)—6V Engine

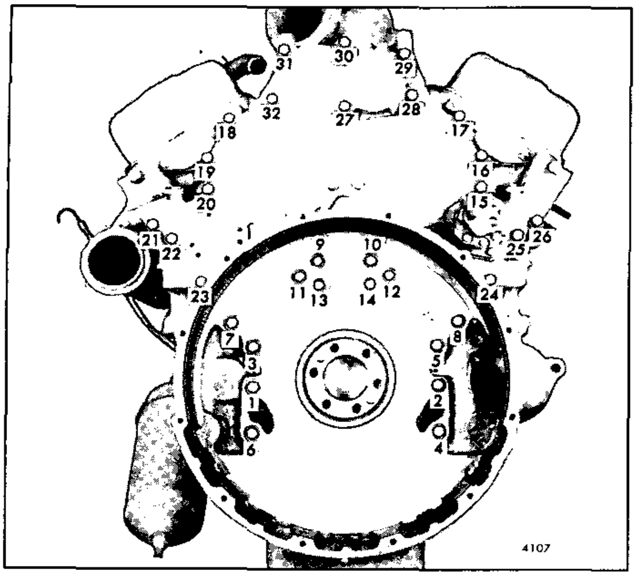


Fig. 8 – Flywheel Housing Bolt Tightening Sequence (Operation 2)—8V Engine

NOTICE: Prior to Engine Serial Numbers 2D–903, 3D–011 and 4D–103, the bolts numbered 7 through 12 in Fig. 3 were all 5/16"–18 bolts and must be tightened to 19–23 lb–ft (26–31 N·m) torque.

b. On the two, three and four cylinder engines, tighten the two 5/16"–18 bolts that secure the top of the governor to the flywheel housing to 10–12 lb–ft (14–16 N·m) torque.

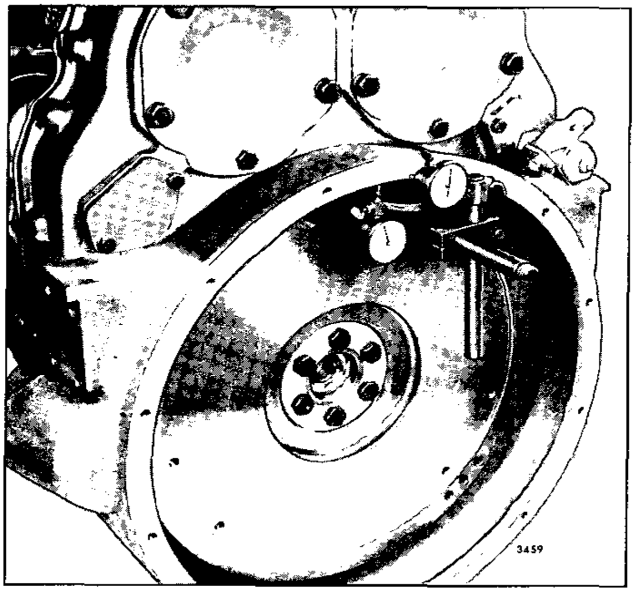


Fig. 9 – Checking Flywheel Housing Concentricity

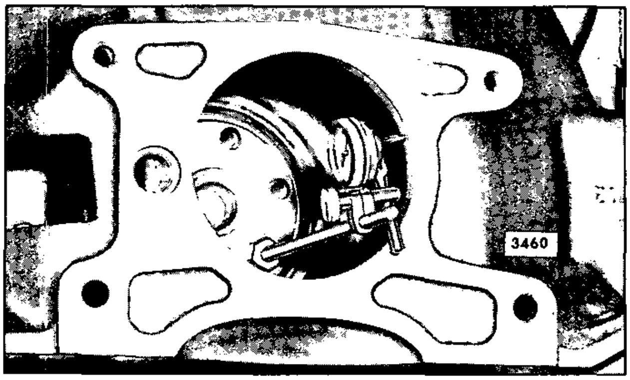


Fig. 10 – Checking Bore Runout

10. Refer to Fig. 7 or 8 for the final bolt tightening sequence for V engines. Then start at No. 1 and tighten the bolts to the specified torque. Tighten the 5/16"–18 bolts (numbers 13 and 14) to 19–23 lb–ft (26–31 N·m) torque and the 3/8"–16 bolts (numbers 9 through 12) to 40–45 lb–ft (54–61 N·m) torque. Tighten the remaining 3/8"–16 and 3/8"–24 bolts to 25–30 lb–ft (34–41 N·m) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell bolt on an 8V engine.

11. On a 6V engine, install the blower and governor drive support assembly as outlined in Section 2.7.1.1 or 2.7.2.1.

12. Install the flywheel (Section 1.4).

13. Check the flywheel housing concentricity and bolting flange face runout with tool J 9737–C, as follows:

    a. Refer to Fig. 9 and thread the base post J 9737–3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

    b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

       If the flywheel extends beyond the housing bell, the bore and face must be checked separately. Use the special adaptor in the tool set to check the housing bore.

    c. Pry the crankshaft toward one end of the block to ensure that end play is in one direction only.

    d. *Adjust each dial indicator to read zero at the twelve o'clock position.* Rotate the crankshaft one full revolution, recording readings at 90° intervals (4 readings each for the bore and the bolting flange face). On "bossed" flywheel housings position the dial indicators at a location where clearance or obstruction is not a problem.

NOTICE: The hex head of the front crankshaft bolt may be used to turn the crankshaft. However, the barring operation should ALWAYS be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

e. Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. Record the readings and interpret as follows:

BORE AND FACE RUNOUT

Check value at six o'clock (6:00) position. This value cannot exceed ± .013″.

Check values at three o'clock (3:00) and nine o'clock (9:00) positions.

3:00	9:00	EXAMPLES	
		Good	Bad
+	+	+ .002″ + .014″ Difference = .012″	+ .002″ + .016″ Difference = .014″
–	–	– .002″ – .014″ Difference = – .012″	– .002″ – .016″ Difference = – .014″

1

1. Both readings "+" or "–". The difference must not exceed .013″.

3:00	9:00	EXAMPLES	
		Good	Bad
+	–	+ .002″ – .010″ Total = .012″	+ .002″ – .012″ Total = .014″
–	+	– .002″ + .010″ Total = .012″	– .002″ + .012″ Total = .014″

2

2. Both readings different, "+/–" or "–/+". The total of dimensions must not .013″.

BORE DIAMETER

Verification of bore diameter is required when 3:00 and 9:00 o'clock readings are both "+" or both "–". The total of dimensions must not exceeed .013″.

3:00	9:00	EXAMPLES	
		Good	Bad
+	+	+ .014″ + .015″ Total = .029″	+ .014″ + .017″ Total = .031″
–	–	– .014″ – .015″ Total = .029″	– .014″ – .017″ Total = .031″

3

f. If the bore or face runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreignmaterial (such as old gasket material) between the flywheel housing and the end plate and between the end plate and the cylinder block.

g. Reinstall the flywheel housing and the flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the bore and face runout and the bore diameter. If necessary, replace the flywheel housing.

14. Install the clutch housing, if used. Tighten the 3/8″–16 attaching bolts to 30–35 lb–ft (41–47 N·m) torque and the 3/8″–24 nuts to 35–39 lb–ft (47–53 N·m) torque.

 a. Install tool J 9748 in one of the crankshaft bolt holes.

 b. Install the dial indicator J 8001–3 and position it to read the bore runout of the housing (Fig. 10). Now check the runout by rotating the crankshaft. The runout should not exceed .008″.

 c. Reposition the dial indicator to read the face runout and rotate the crankshaft. The maximum allowable runout is .008″.

 d. If the bore or face runout is excessive, loosen the housing attaching bolts and nuts slightly and tap the housing with a soft hammer in the required direction until the runout is within limits. Tighten the attaching bolts and nuts evenly to 30–35 and 35–39 lb–ft (41–47 and 47–53 N·m) torque respectively. Then recheck the runout.

15. Install the fuel pump (V–type engine), if removed.

16. Use a new gasket and install the oil pan. On 8V engines, if the flywheel housing and oil pan include outriggers for the installation of reinforcement bolts, be sure the oil pan butts up against the flywheel housing before tightening the oil pan bolts. Install and tighten the 1/2″–13 reinforcement bolts.

17. Remove the engine from the overhaul stand and complete assembly of the engine.

PISTON AND PISTON RINGS

TRUNK TYPE PISTON

The trunk type malleable iron piston (Fig. 1) is plated with a protective coating of tin which permits close fitting, reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray.

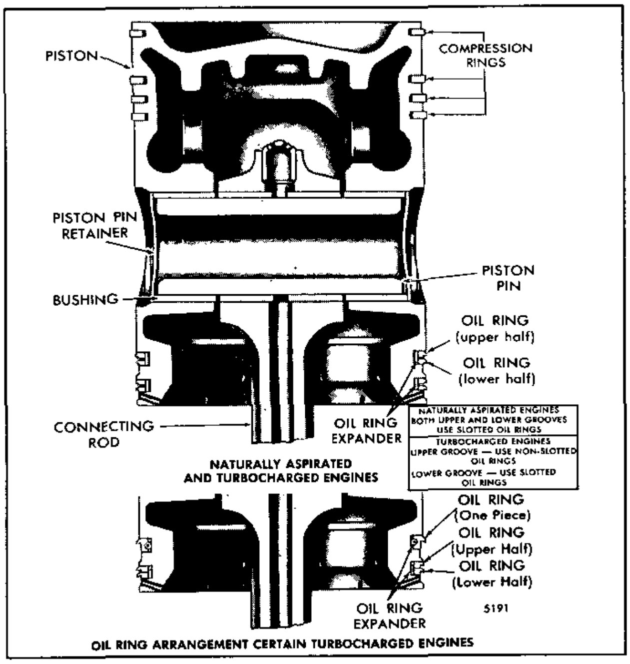


Fig. 1 – Typical Trunk Type Piston Assembly

Each piston is internally braced with fin–shaped ribs and circular struts, scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston and indirectly by the water jacket around the cylinder.

Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt.

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin (1.375″ diameter). After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a steel retainer. Thus, lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

The current piston pin retainer (formerly colored black) for the 1.375″ diameter piston pin has a greater outside diameter (1.6110″) and is now brass colored for identification. The former and new retainers are interchangeable in an engine. When rebuilding a turbocharged engine with the 1.375″ diameter piston pin, use only the current retainer.

Effective with engine serial numbers 3D–170958, 4D–181763 and 6D–187523, turbocharged engines use a 1.500″ diameter piston pin. With the use of the 1.500″ diameter piston pin, new piston assemblies, piston pin retainers and connecting rod assemblies are required. The former piston pin diameter is 1.375″. The former and new piston and connecting rod assemblies differ only in that they have larger bushing bores to facilitate the installation of new, larger diameter bushings. The larger bushing inner diameter is necessary to accommodate the new, larger piston pin. Because of the larger pin diameter, former and new parts are not separately interchangeable. When it becomes necessary to replace any one of the three major cylinder components, it will be necessary to include the other two to assure interchangeability. Current piston assemblies and connecting rods can be mixed in an engine with the former piston assemblies and connecting rods.

Turbocharged engines incorporate pistons and connecting rod assemblies which utilize "vapor blasted" piston pin bushings. Vapor blasting is a surface finishing process which is applied to the bushing after it is installed and finished bored in the piston or rod. This process cannot be performed in the field. Piston pin bushings may not be replaced in turbocharged engines and when excessive wear exists it will be necessary to replace the piston and/or connecting rod assembly.

Each piston is fitted with compression rings and oil control rings (Fig. 1). Equally spaced drilled holes just below each oil control ring groove permits excess oil, scraped from the cylinder walls, to return to the crankcase.

A new fire ring (top compression ring), prestressed for increased durability, has been released for Series 53 naturally aspirated (NA) engines effective with 3D–189578, 4D–203354 and 6D–223676. The fire ring is identified with the word "TOP" stamped adjacent to the gap and a permanent oval mark on top to indicate prestressing. Current turbocharged engine fire ring (identified by a black oxide coating and a permanent oval mark on top to indicate prestressing) will continue to be available to service turbocharged engines. The chrome facing on both the new NA engine fire ring and the current turbocharged engine fire ring has been increased for improved wear characteristics.

• Two service–only piston ring sets are available for engines operating at light loads or with extended idle periods where high oil consumption or wet stacking may be a concern. These have a tapered face, grooved fire ring, barrel–face compression rings, two–piece oil control rings in each groove, and 5–10 lb tension expanders.

The upper drain holes in the oil ring groove and the "J" relief are omitted on built engines. The piston pins are polished and drilled for positive piston pin bushing lubrication.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the oil pan.
3. Remove the oil pump and inlet and outlet pipes, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then, remove the rings and connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (Fig. 2).
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushings.

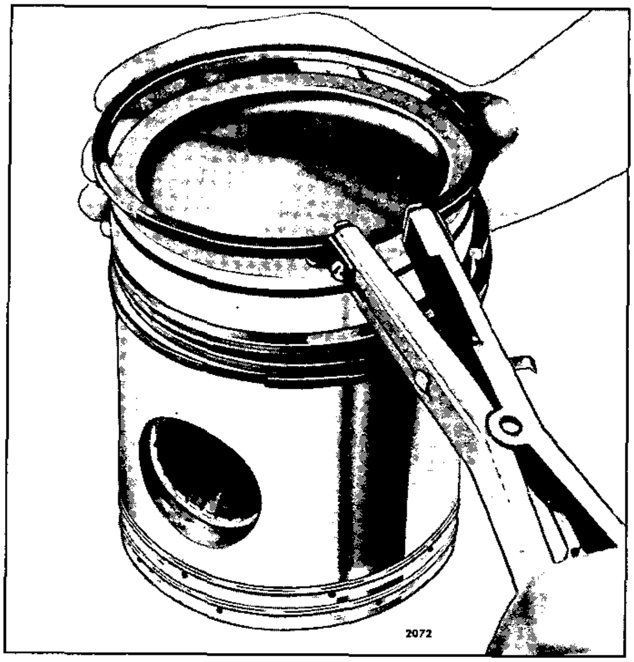


Fig. 2 – Removing or Installing Piston Ring Using Tool J 8128

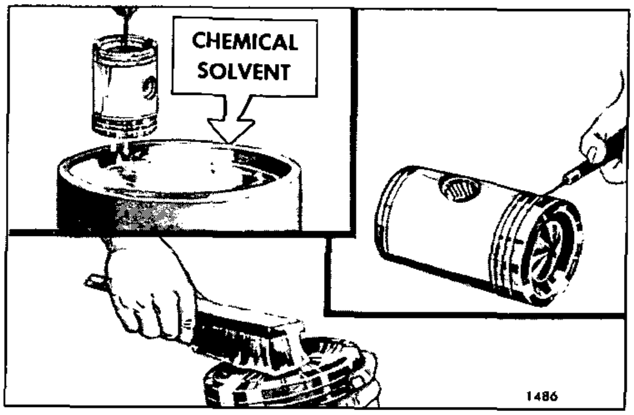


Fig. 3 – Cleaning Piston

3. Withdraw the piston pin from the piston, then remove the connecting rod.
4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Clean Piston

Clean the piston components with fuel oil and dry them with compressed air.

• **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

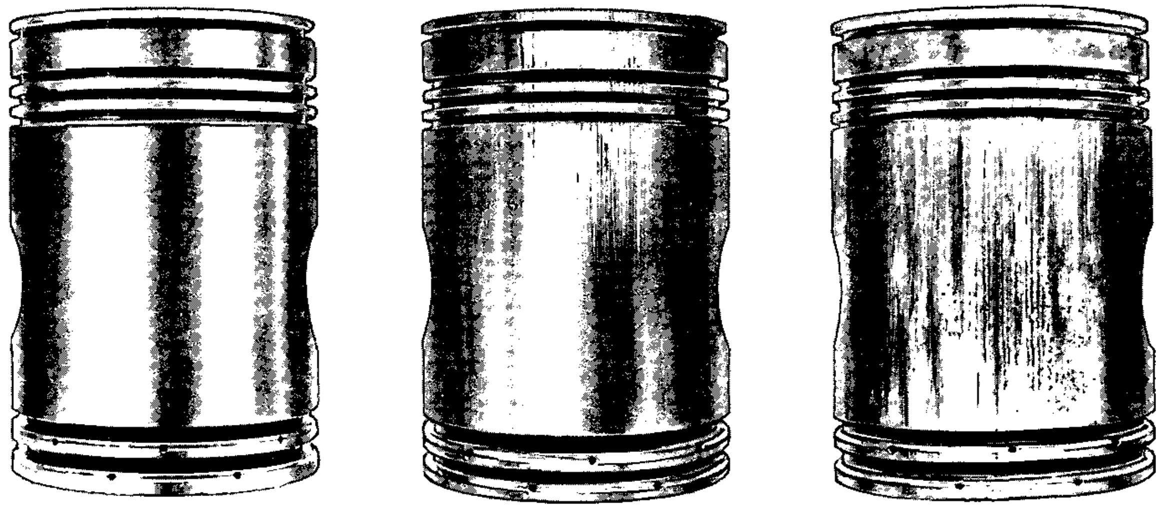


Fig. 4 – Comparison of Pistons

If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 3) that will not harm the piston pin bushings or the tin–plate on the piston.

The upper part of the piston, including the compression ring lands and grooves, is not tin–plated and may be wire–brushed to remove any hard carbon. However, use care to avoid damage to the tin–plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston and the oil drain holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

Inspection

If the tin–plate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which may be cleaned up and reused (Fig. 4). Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage.

Replace the piston if cracks are found across the internal struts.

Check the cylinder liner and block bore for excessive out–of–round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for Specifications).

Inspection of the connecting rod and piston pin are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull–over from the air cleaner, dribbling injectors, combustion blow–by and low oil pressure (dilution of the lubricating oil).

Inspect and measure the piston pin bushings. The piston pin–to–bushing clearance with new parts is .0025" to .0034". A maximum clearance of .010" is allowable with worn parts. The piston pin bushings in the connecting rod are covered in Section 1.6.1.

Remove Bushings from Piston

1. Place the piston in the holding fixture J 1513–1 so that the bushing bores are in alignment with the hole in the fixture base.

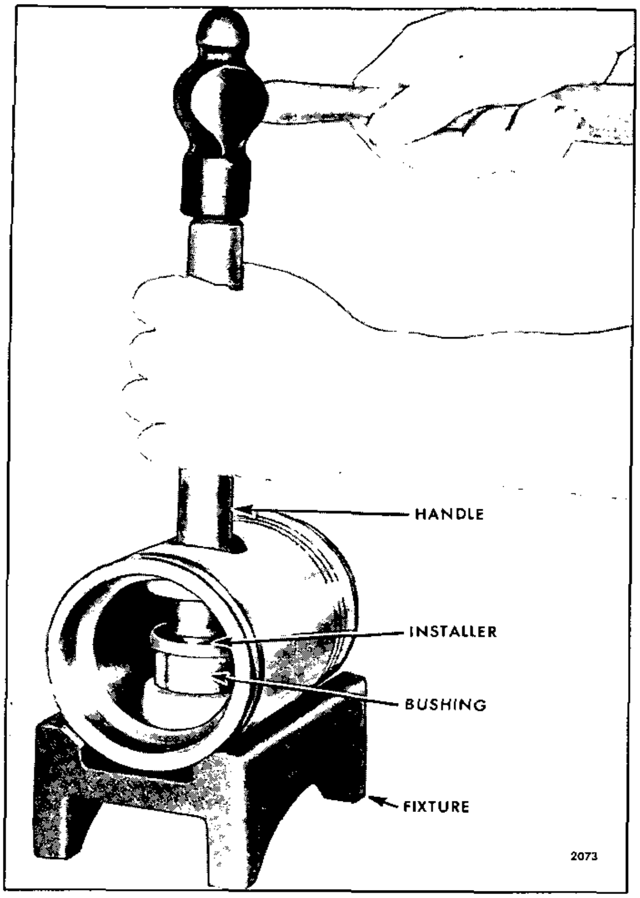


Fig. 5 – Removing or Installing Piston Pin Bushings

Do not remove the bushings from the pistons used in turbocharged engines because they are not serviced separately.

2. *Drive each bushing from the piston* (non–turbocharged engines) with the bushing remover J 4972–4 and handle J 1513–2 (Fig. 5).

Install Bushings in Piston

1. Place the spacer J 7587–1 in the counterbore in the fixture J 1513–1 (small end up).
2. Place the piston on the fixture so that the spacer *protrudes into the bushing bore.*
3. Insert the installer J 4972–2 in a bushing, then position the bushing and installer over the lower bushing bore. Locate the joint in the bushing toward *the bottom of the piston* (Fig. 6).
4. Insert the handle J 1513–2 in the bushing installer and drive the bushing in until it bottoms on the spacer.
5. Install the second bushing in the same manner.
6. The bushings must withstand an end load of 1,800 pounds without moving after installation.

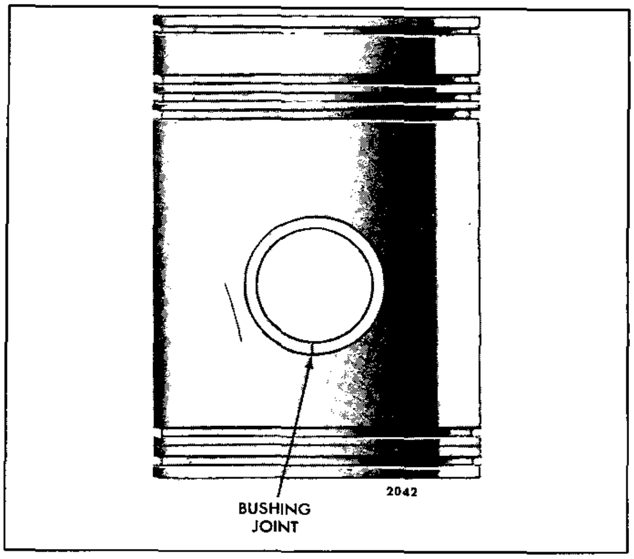


Fig. 6 – Location of Joint in Piston Pin Bushings

7. Ream the bushings to size as follows:

   a. Clamp the reaming fixture J 5273 in a vise (Fig. 7). Then, insert the guide bushing J 4970–5 in the fixture and secure it with the set screw.

   b. Place the piston in the fixture and insert the pilot end of the reamer J 4970–4 through the clamping bar, bushings and into the guide bushing.

   c. *With the piston, fixture and reamer in* alignment, tighten the wing nuts securely.

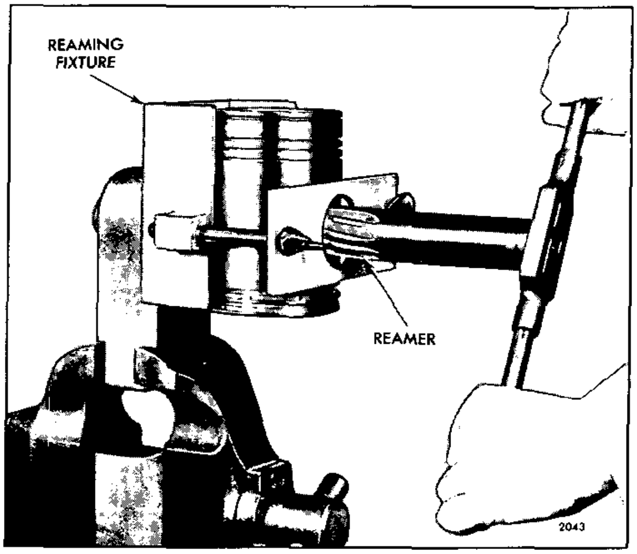


Fig. 7 – Reaming Piston Pin Bushings

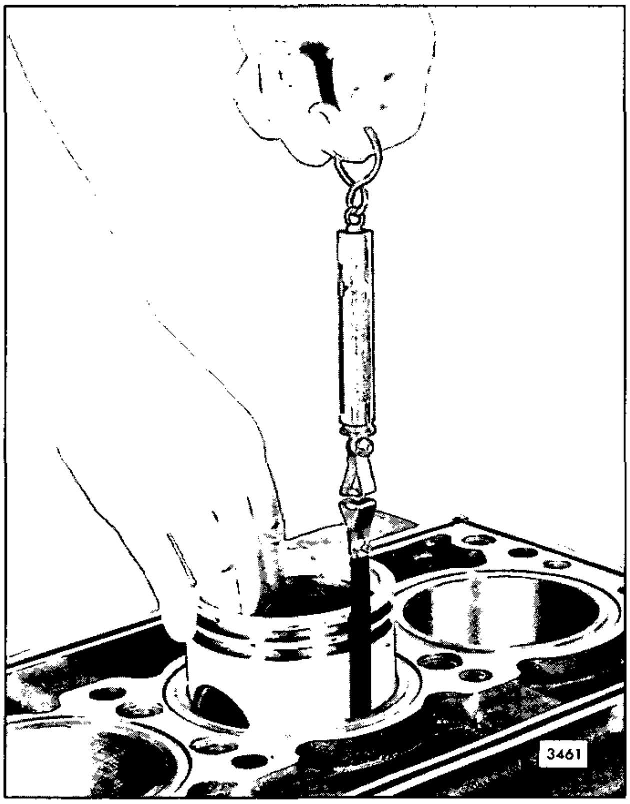


Fig. 8 – Measuring Piston–to–liner Clearance

d. Ream the bushings (Fig. 7). Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.3775" to 1.3780".

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). The taper and out–of–round must not exceed .0005". Refer to Section 1.0 for piston diameter Specifications.

A new cylinder liner has an inside diameter of 3.8752" to 3.8767". The piston–to–liner clearance, with new parts, is .0027" to .0068" (non–turbocharged engines) or .0047" to .0088" (turbocharged engines). A maximum clearance of .010" (non–turbocharged engines) or .012" (turbocharged engines) is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places 90° apart (Fig. 8).

Use feeler gage set J 5438–01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001" greater than the thickness of the feeler gage used, i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings and two oil control rings (Fig. 1).

The current top compression (fire) ring can be identified by the bright chrome on the bottom side and oxide (rust color) on the top. The former ring had a plain metal color on both sides.

A two–piece oil control ring is used in both oil ring grooves in the pistons for non–turbocharged (naturally aspirated) engines. A one–piece oil control ring is used in the upper ring groove and a two–piece ring in the lower ring groove in the pistons for turbocharged engines. Brazil built engines use non–slotted upper oil control rings and low tension expanders.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then, measure the ring gap with a feeler gage (Fig. 9). Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015".

Check the ring side clearance (Fig. 10). Ring side clearances are specified in Section 1.0.

• Lubrication

Use a mixture of clean engine oil and *STP* (or equivalent) on all moving parts of the cylinder kit during assembly. This mixture adheres to the parts for a longer period of time than plain engine oil, thus helping prevent

scuffing of parts at engine start–up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part *STP*, or equivalent).

Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under *Assemble Connecting Rod to Piston* in Section 1.6.1. Then, refer to Fig. 1 and install the piston rings. Lubricate the piston rings and piston with the clean engine oil *STP* mix before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 (Fig. 2). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. When installing the top compression (fire) ring with the tapered face, be sure the side marked "TOP" is toward the top of the piston.
2. *Stagger the ring gaps around the piston.*

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons for *naturally aspirated and turbocharged* engines consist of two halves (upper and lower). The upper oil control ring used on pistons for certain *turbocharged* engines is a one–piece ring while the lower ring is a two–piece ring (upper and lower halves). Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston.

   NOTICE: When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

2. To install the one–piece ring on certain turbocharged engines, position it over the upper ring groove, using tool J 8128, with the gap 180° from the gap in the expander and the scraper edge facing down. Press the *ring against the gap side of the expander to prevent the* ends of the expander from overlapping, then align the ring with the groove and release the tension on the tool, permitting the ring to slip in position.

   Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then, install the lower half with the gap 45° from the gap in the upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston). The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

3. Install the upper and lower halves of both oil control rings (naturally aspirated and turbocharged engines) as outlined above.

If there is a noticeable resistance during installation of the piston, check for an overlapped ring expander.

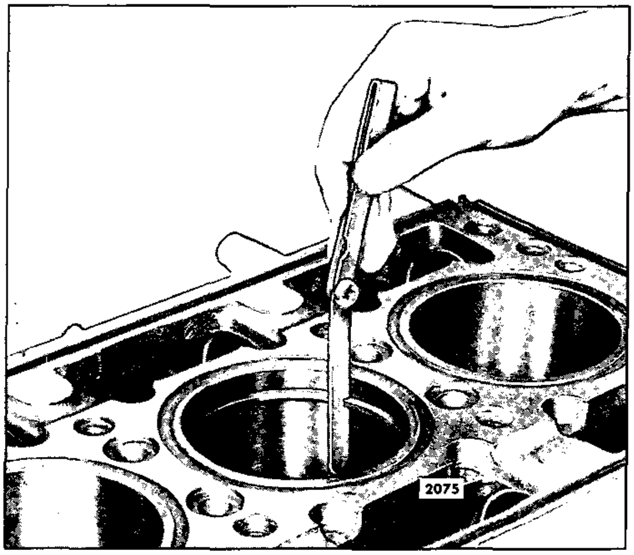


Fig. 9 – Measuring Piston Ring Gap

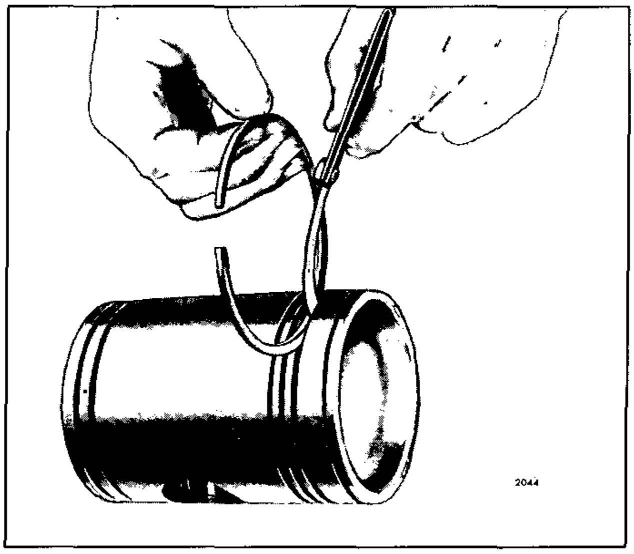


Fig. 10 – Measuring Piston Ring Side Clearance

CROSS–HEAD TYPE PISTON

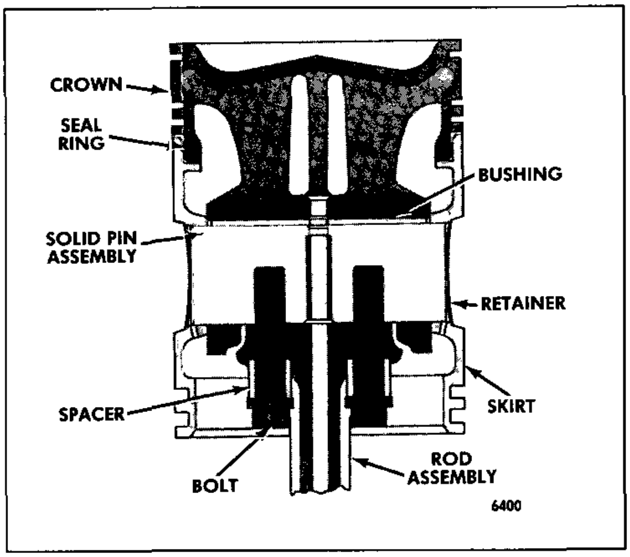


Fig. 11 – Cross–Head Piston and Connecting Rod Assembly

The cross–head piston (Figs. 11 and 12) is a two–piece piston consisting of a crown and skirt. A fluoroelastomer oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 150° slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counterbores. Equally spaced drain holes are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase. A lubricating oil hole is drilled through the solid piston pin. Two bolts and spacers are used to attach the connecting rod to the piston pin.

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is pressure–fed up the drilled passage in the connecting rod, through the oil tube in the piston pin, then through the center hole in the bushing to the underside of the piston crown. A portion of the oil flows along the grooves in the bushing to lubricate the piston pin.

During engine operation, gas loads pushing down on the piston crown are taken directly by the piston pin and bushing. The piston skirt, being separate, is free from vertical load distortion; thermal distortion is also reduced as the piston crown expands. As the connecting rod swings to one side during downward travel of the piston, the major portion of the side load is taken by the piston skirt.

In cross–head piston equipped engines, a complete new balance weight system is used. When replacing trunk–type pistons with cross–head pistons, new camshaft front pulleys (integral weight) plus new bolt–on weights on the rear camshaft gears (Sections 1.7.2 and 1.7.3) must be used.

- New cross–head pistons and rings, connecting rods, and cylinder liners became standard in all turbocharged industrial engines equipped with bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545.

- A new high–durability piston dome with 14% thicker standpipe struts for improved dome support became standard on all cross–head pistons approximately May 24, 1988.

- **NOTICE:** Cross–head pistons and trunk–type pistons must not be used together in an engine. The difference in weight of the pistons will affect engine balance. Failure to observe this precaution can result in serious engine damage.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

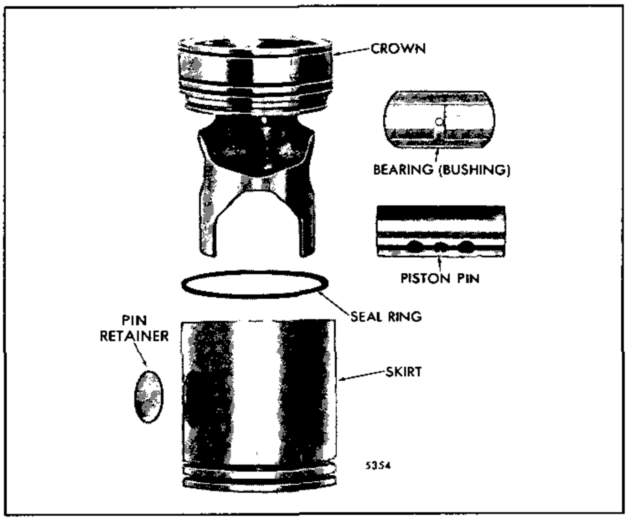


Fig. 12 – Cross–Head Piston and Connecting Rod Components

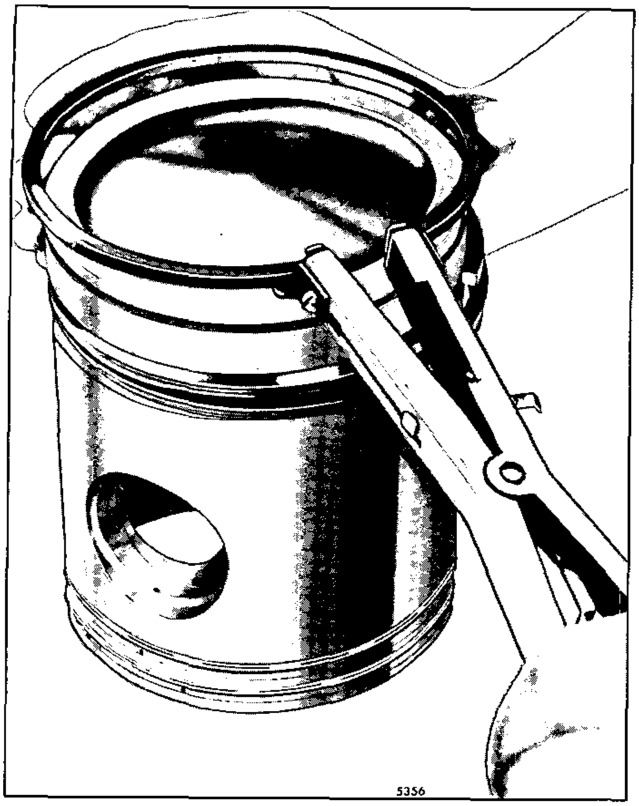


Fig. 13 – Removing or Installing Piston Rings with Tool J 8128

Remove Piston and Connecting Rod

1. *Drain the cooling system.*
2. Drain the oil and remove the oil pan.
3. Remove the oil pump inlet pipe, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

• Fluoroelastomer (Viton) Caution

Under normal design conditions, fluoroelastomer (Viton) parts, such as crown–to–skirt seal rings, are perfectly safe to handle. However, a potential hazard may occur if these components are raised to a temperature above 600°F (316°C), such as during a cylinder failure or engine fire. At temperatures above 600°F (316°C) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

CAUTION: To avoid personal injury, wear goggles or a faceplate and neoprene or PVC gloves when handling fluoroelastomer seals which have been degraded by excess heat. Make sure engine parts have cooled before handling them. If hydrogen fluoride condensate is expected, wash equipment and parts well with lime water (calcium hydroxide solution) before reusing. Discard gloves after handling degraded fluoroelastomer.

Disassemble Piston and Connecting Rod

Piston assembly components should be match–marked during disassembly to ensure that they are reassembled in the same position. Note the condition of the piston and rings. Then, remove the rings and disassemble the piston, as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (Fig. 13).
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushing. Remove the opposite retainer in the same manner.
3. Loosen the two bolts which secure the connecting rod to the piston pin. Then, remove the rod and piston assembly from the vise and place the assembly on the bench. Remove the two bolts and spacers and remove the connecting rod.
4. Withdraw the piston pin.
5. Separate the piston skirt from the piston crown. Tool J 33048 may be used to aid in disassembling the dome from the skirt, of piston assemblies using fluoroelastomer seal rings. The piston assembly should be grasped by the skirt, and the pin area of the dome brought down onto the neoprene head of the tool with sufficient force to separate the dome from the skirt. The neoprene–padded base of the tool will absorb the impact of any dropped piston skirt.

CAUTION:To reduce the risk of personal injury when disassembling the piston dome from the skirt, keep fingers out of the piston pin hole and wear steel-toed shoes.

6. Remove the seal ring from the piston crown.
7. Remove the piston pin bushing (bearing).

Cleaning

Clean the piston components with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

If fuel oil does not remove the carbon deposits, use an approved chemical solvent that will not harm the tin-plate on the piston skirt. Do not use chemical solvent on the bushing.

The piston crown, including the compression ring grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. *Do not wire-brush the piston skirt.* Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston crown and skirt and the oil drain holes in the lower half of the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

Glass beading can be used to clean a piston crown. Mico Bead Glass Shot MS-M (.0029" - .0058") is recommended. Allowable air pressure is 80-100 psi (552-689 kPa). After cleaning, do not leave glass beads in the piston crown.

NOTICE: Do not attempt to clean the piston skirt by glass beading, as it will remove the tin-plating.

Use crocus cloth wet with fuel oil to remove any trace of fretting and/or corrosion on the connecting rod saddle-to- piston pin contact surface. Do not use crocus cloth on the bushing side of the pin. Polishing or refinishing the piston pin on the bushing side is not recommended.

Inspection

If the tin-plate on the piston skirt and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored piston skirts, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise, a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston skirt and crown for score marks, cracks, damaged ring groove lands or indications of overheating. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for Specifications).

Inspection of the connecting rod, piston pin and piston pin bushing are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

• Crosshead Piston Dome Inspection

Before reusing a crosshead piston dome, inspect the dome for serviceability, using the magnetic particle or fluorescent magnetic particle inspection method. In both cases, the direction of magnetism must be proper to assure finding the cracks of concern.

Magnetic Particle Method - Magnetize the dome, then cover with a fine magnetic powder (dry) or solution (wet). Flaws such as cracks will form small local magnets which will attract the metallic particles, effectively marking the crack. Demagnetize the dome and clean throughly after completing the test.

Fluorescent Magnetic Particle Method - This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "Black Light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "Black Light".

If magnetic particle inspection reveals a crack in any strut of a crosshead piston dome, the dome must be discarded and replaced.

NOTICE: Reusing a crosshead piston dome with a cracked strut can result in dome separation and serious engine damage.

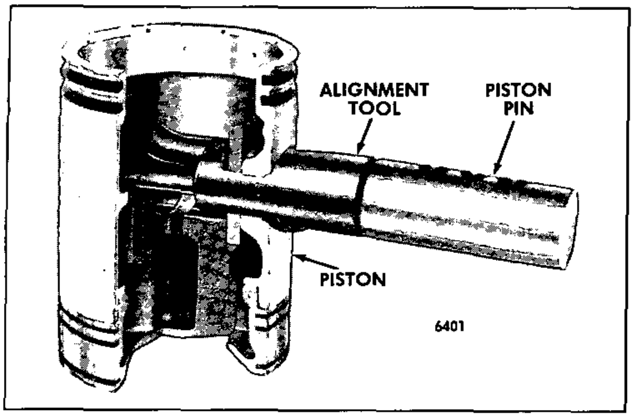


Fig. 14 – Installing Piston Pin Using Alignment Tool J 35619

When conducting a magnetic particle inspection, make sure that a casting joint is not mistaken for a crack.

• Lubrication

Use a mixture of clean engine oil and *STP* (or equivalent) on all moving parts of the cylinder kit during assembly. This mixture adheres to the parts for a longer period of time than plain engine oil, thus helping prevent scuffing of parts at engine start–up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part *STP*, or equivalent).

Assemble Piston and Connecting Rod

1. Refer to Section 1.0 (Shop Notes and Specifications) on reusing piston assembly components.
2. *Install the bearing (bushing) in the piston crown. It* should slide into the piston crown without force. With new parts, there is .0005" to .0105" clearance between the edge of the bushing and the groove in the piston crown. The bearing must be installed before assembling the piston skirt and crown.
3. Lubricate the seal ring with engine oil and install in the groove on the piston crown. Allow time for the seal to return to its original shape before installing the skirt. *Excessive stretching should be avoided.*.
4. The fluoroelastomer seal ring can be compressed by hand when the skirt is pushed into position on the piston crown. Lubricate the seal with engine oil. Before completely assembling the piston, check to make sure the seal ring does not roll out of the groove during assembly. This condition can cause the skirt to cock *with respect to the dome. This may result in premature* piston wear or the inability to install the piston in the liner. This condition is evidenced by the non–uniform clearance between the dome and the skirt after assembly. This condition may be corrected by cleaning the skirt counterbore with crocus cloth the remove any tin or sharp edge that may be pulling the seal out of the groove.
5. Lubricate the piston pin with clean engine oil and *install it (Fig. 14).*

   NOTICE: Line up the piston pin opening in the piston skirt with the bearing (bushing) opening in the piston crown to prevent damage to the pin or bushing.

6. *Install the spacers on the two 3/8"–24 x 1.88"* connecting rod to piston pin attaching bolts.
7. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact contact surfaces.
8. Install and tighten the bolts finger tight. Then, clamp the connecting rod in a vise and tighten the bolts to 30–35 lb–ft (41–47 N·m) torque (Fig. 15). Do not exceed this torque.
9. Place a new piston pin retainer in position. Then, place the crowned end of installer J 35572 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Fig. 16).
10. Install the second piston pin retainer in the same manner. Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counterbores. The width of the land should be even around the retainer.
11. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushing, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987–01 (Fig. 17). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

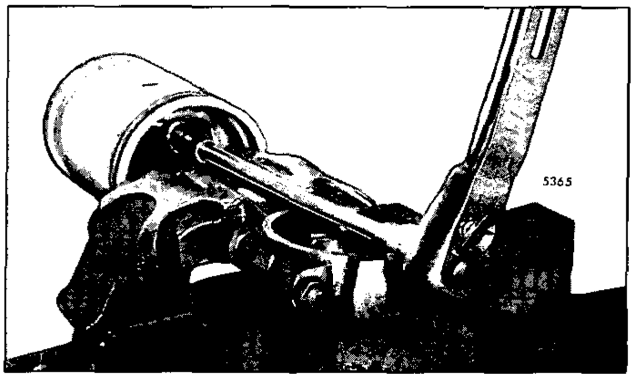


Fig. 15 – Tightening Connecting Rod to Piston Pin Bolts

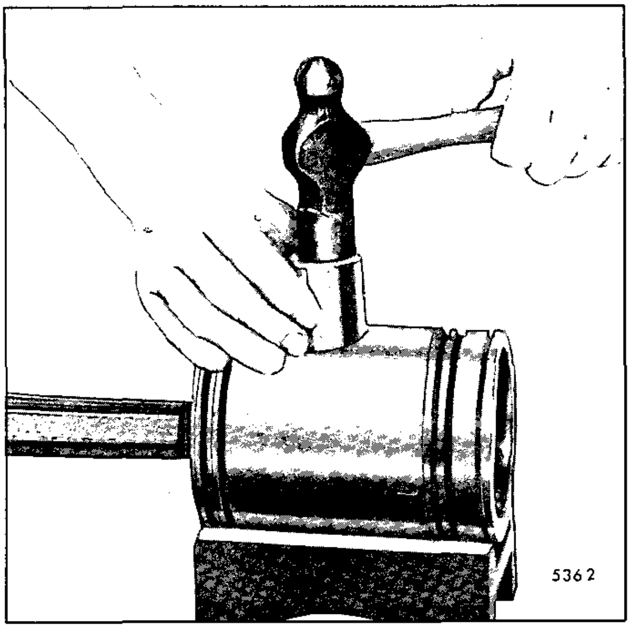


Fig. 16 – Installing Piston Pin Retainer Using Tool J 35572

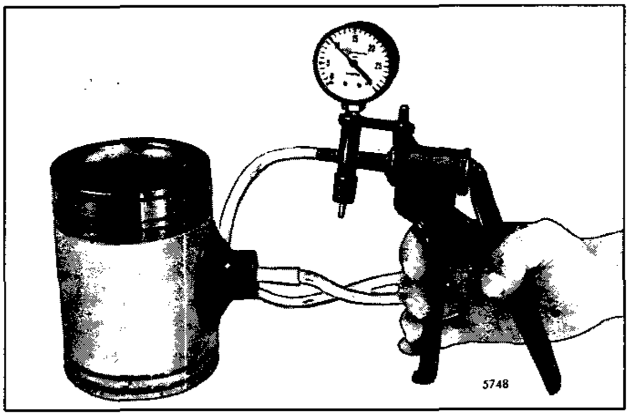


Fig. 17 – Checking Piston Pin Retainer for Proper Sealing with Tool J 23987-01

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). Refer to Section 1.0 for Specifications.

The piston–to–liner clearance, with new parts, will vary with the particular piston and cylinder liner (refer to Section 1.0). A maximum clearance of .012″ is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner and check the clearance in four places 90° apart (Fig. 18).

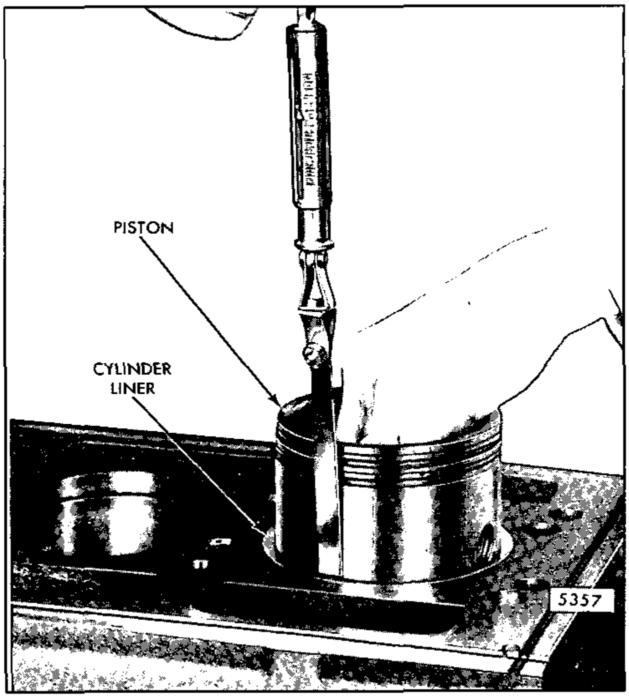


Fig. 18 – Measuring Piston–to–Liner Clearance with Tool J 5438-01

Use feeler gage set J 5438–01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001″ greater than the thickness of the feeler gage used, i.e., a .004″ feeler gage will indicate a clearance of .005″ when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, two compression rings and two oil control rings (Fig. 19).

The top (fire) ring is pre–stressed. It is identified by a small indentation mark on the top side.

A new "wide gap" prestressed fire ring and a new one piece new upper oil control ring and expander are being used on cross–head pistons. The fire rings differ only in their width dimensions. The trunk type piston ring has a .0804″–.0820″ width. The cross–head piston ring has a .1034″–.1050″ width.

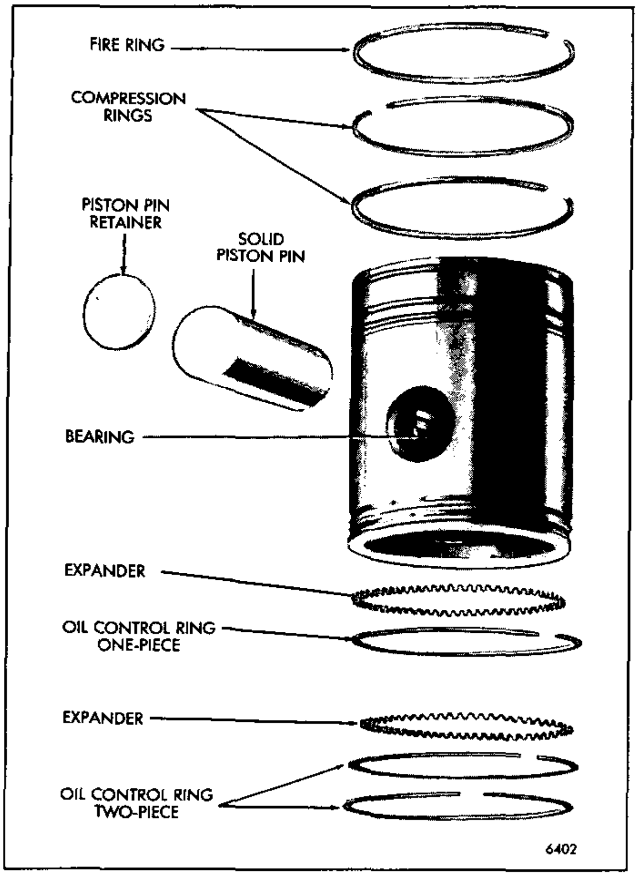


Fig. 19 – Piston Ring Location

A one–piece oil control ring in the upper ring groove and a two–piece ring in the lower ring groove are used in the cross–head pistons for *turbocharged* engines (Fig. 22).

The former and new fire rings, upper groove oil control rings and expanders are not functionally interchangeable. The new components must be used together on cross–head piston equipped turbocharged engines. The former fire ring will continue to be used in production and service for engines *with trunk type pistons. The former oil control ring and* expander will continue to be used in the upper oil control ring groove of trunk type pistons.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed. Refer to the parts catalog or microfiche to select the current piston rings for a particular engine.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston skirt to push the ring down to be sure it is parallel with the top of the liner. Then, measure the ring gap with a feeler gage (Fig. 20). Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015".

Check the ring side clearance (Fig. 21). Ring side clearances are specified in Section 1.0.

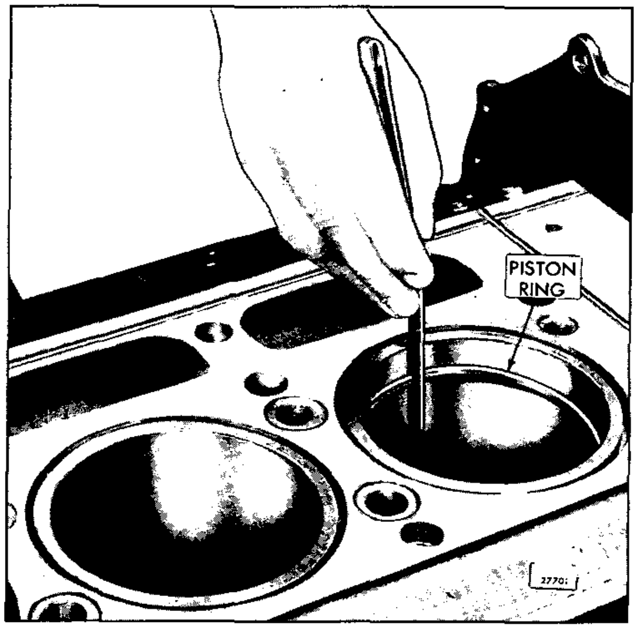


Fig. 20 – Measuring Piston Ring Gap

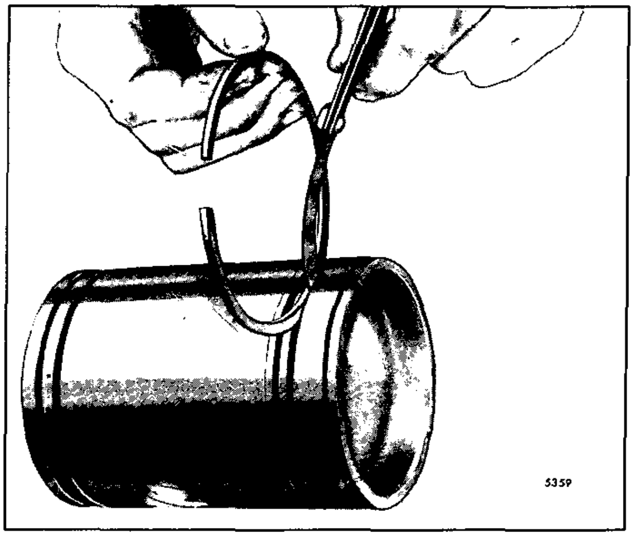


Fig. 21 – Measuring Piston Ring Side Clearance

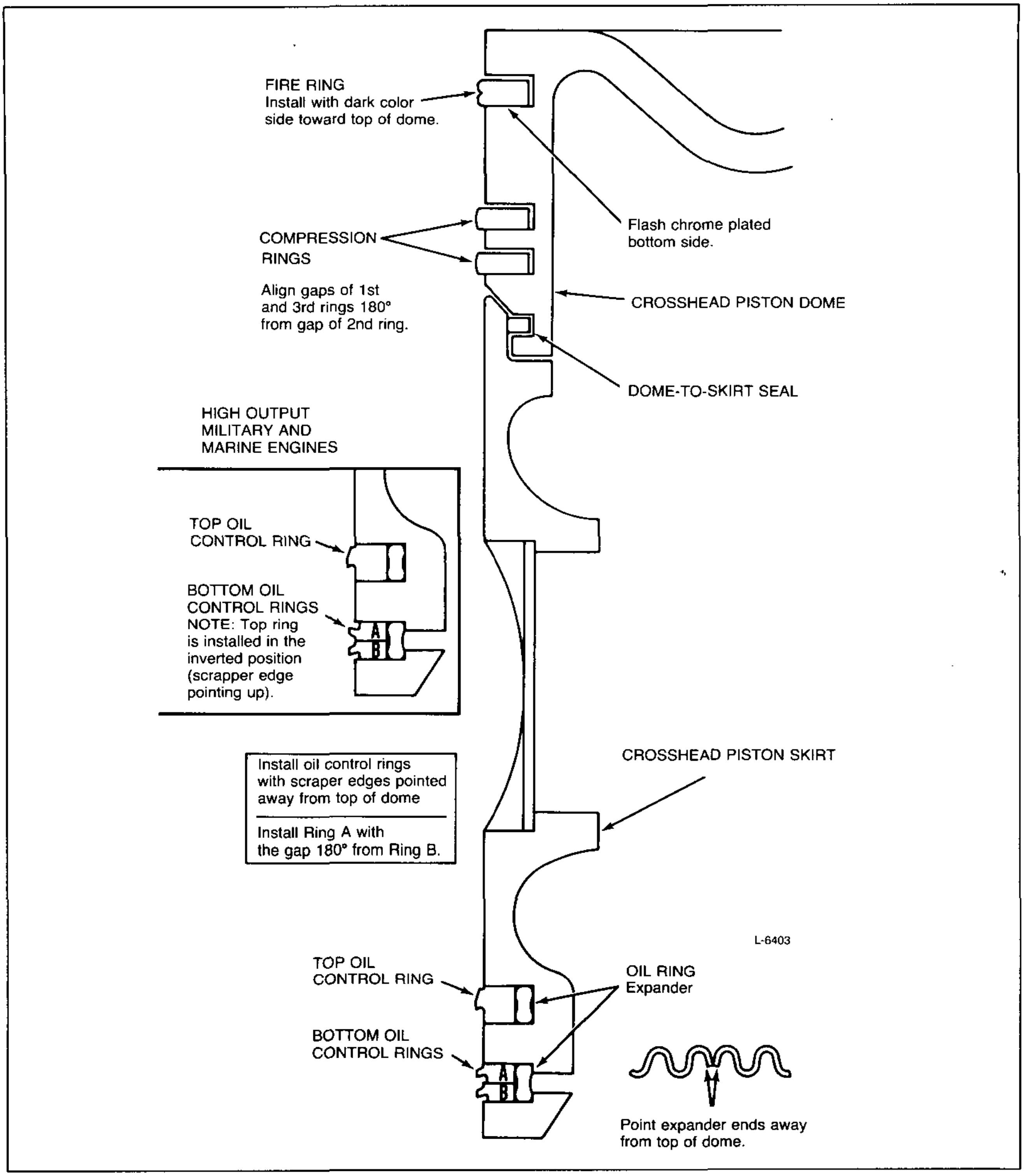


Fig. 22 – Piston Ring Installation Instructions

Install Piston Rings

Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 (Fig. 13). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Fig. 22 for ring identification and location.
2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

Refer to Fig. 22 for the type and location and install the oil rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption. When peripheral abutment type ring expanders are used, install them with the legs of the free ends toward the bottom of the piston. Noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped. Corrective action should be taken to prevent ring breakage before this occurs.
2. Install the oil control rings by hand. Start with the top oil ring and align the gaps as indicated in Fig. 22. The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control, except on high output military and marine engines (Fig. 22).

Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

CONNECTING ROD

TRUNK TYPE PISTON

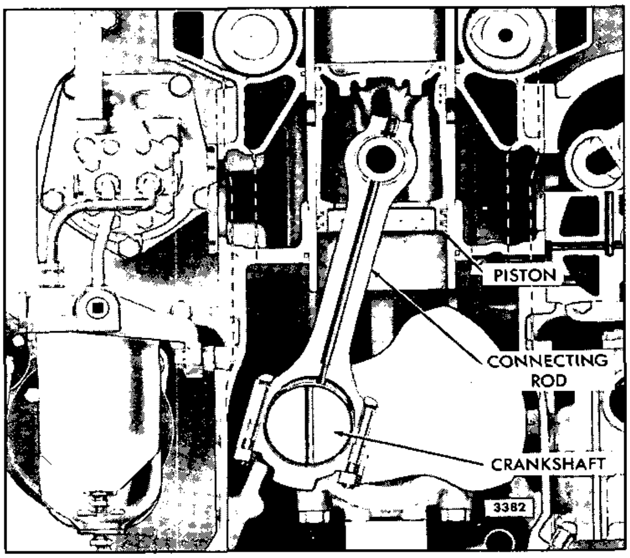


Fig. 1 – Connecting Rod Mounting

Each connecting rod is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end (Figs. 1 and 2). The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head on engines equipped with an oil cooler. Engines that are not equipped with an oil cooler do not use nozzle type connecting rods. An orifice is pressed into a counterbore at the lower end of the oil passage (in rods equipped with a spray nozzle) to meter the flow of oil.

Never intermix nozzle type connecting rods in an engine with non–nozzle type connecting rods.

A helically–grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

The turbocharged engine connecting rods include vapor blasted bushings and increased width oil grooves.

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle (if used), orifice and the piston pin bushings pressed in place and bored to size.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

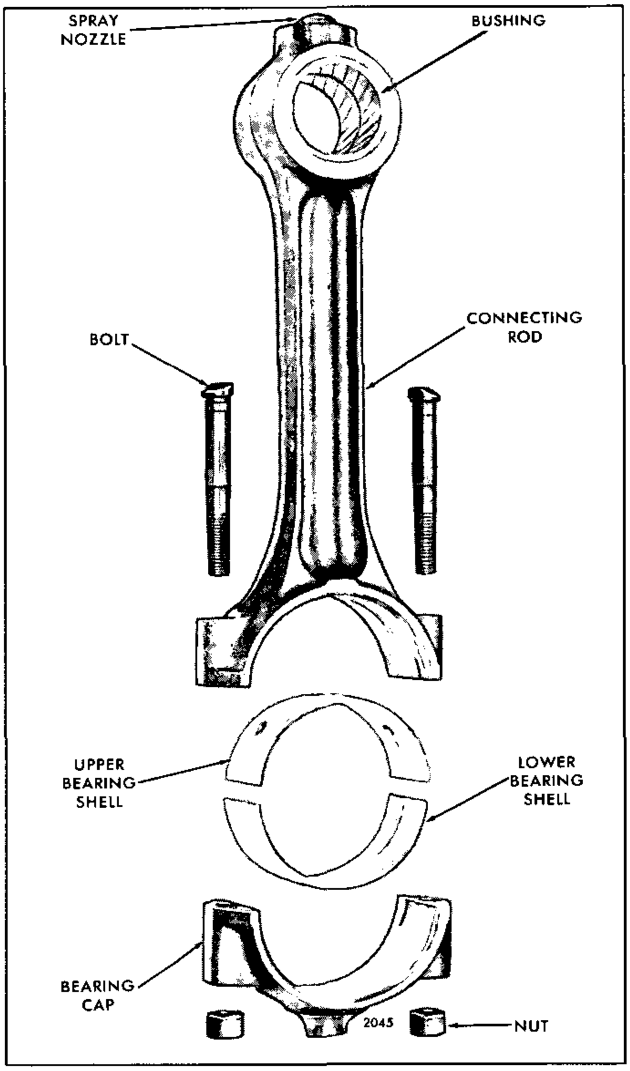


Fig. 2 – Connecting Rod Details and Relative Location of Parts

Effective with engine serial numbers 3D–170958, 4D–181763 and 6D–187523, turbocharged engines use a 1.500″ diameter piston pin. With the use of the 1.500″ diameter piston pin, new piston assemblies, piston pin retainers and connecting rod assemblies are required. The former piston pin diameter is 1.375″. The former and new piston and connecting rod assemblies differ only in that they have larger bushing bores to facilitate the installation of new, larger diameter bushings. The larger bushing inner diameter is necessary to accommodate the new, larger piston pin.

Because of the larger pin diameter, former and new parts are not separately interchangeable. When it becomes necessary to replace any one of the three major cylinder components, it will be necessary to include the other two to assure interchangeability. Current piston assemblies and connecting rods can be mixed in an engine with the former piston assemblies and connecting rods.

- New cross–head pistons and rings, connecting rods, and cylinder liners became standard in all turbocharged industrial engines equipped with bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545.

NOTICE: Do not mix trunk style pistons and cross–head pistons in the same engine. The difference in weight will affect engine balance. Failure to observe this precaution can result in serious engine damage.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod, as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage and spray holes are not clogged.

Visually check the connecting rod for twist or bending. Check for cracks (Fig. 3) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage and spray holes are not clogged. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Check the connecting rod bushings for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin, bushings and spray nozzle.

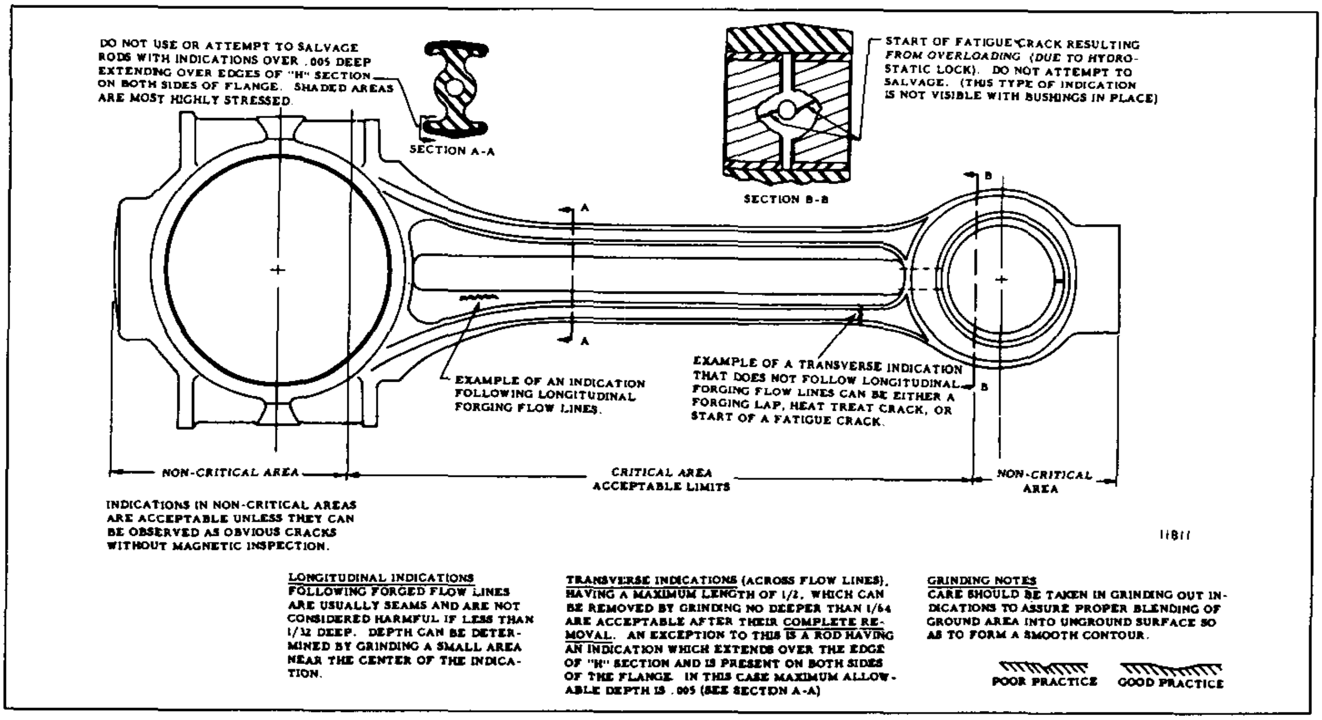


Fig. 3 – Magnetic Particle Inspection Limits for Connecting Rod

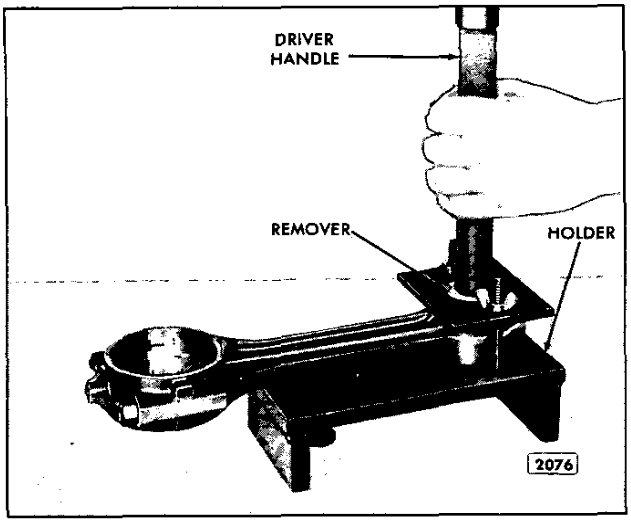


Fig. 4 – Removing or Installing Bushings

Turbocharged engines with trunk type pistons use two different diameter piston pins with a special surface finish. Engines built prior to 3D–170958, 4D–181763 and 6D–187523 have a 1.375" diameter piston pin. Those built after have a 1.500" diameter piston pin, except marine applications which continue to use the 1.375" diameter piston pin.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

Since it is subjected to downward loading only, free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to .010" are satisfactory.

Remove Bushings

If it is necessary to replace the connecting rod bushings, remove them as follows:

Do not remove the bushings from the connecting rods used in turbocharged engines because they are not serviced separately.

1. Clamp the upper end of the connecting rod in holder J 7632 (Fig. 4) so that the bore in the bushings is aligned with the hole in the base of the holder.
2. Place the bushing remover J 4972–4 in the connecting rod bushing, insert handle J 1513–2 in the remover and drive the bushings from the rod.

Replace Spray Nozzle

The connecting rod bushings must be removed before the spray nozzle can be replaced. The orifice in the lower end of the drilled passage in the connecting rod is not serviced and it is not necessary to remove it when replacing the spray nozzle.

Replace the spray nozzle, as follows:

1. Remove the connecting rod bushings (non–turbocharged engines only).
2. Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin, in the curved side of the tool, in the opening in the bottom of the spray nozzle.
3. Support the connecting rod and tool in an arbor press (Fig. 5).
4. Place a short sleeve directly over the spray nozzle. Then, press the nozzle out of the connecting rod.
5. Remove the tool.
6. Start the new spray nozzle straight into the counterbore in the connecting rod.
7. Support the connecting rod in the arbor press, place a short 3/8" I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.
8. Install new bushings in the connecting rod.

Install Bushings

1. Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool (Fig. 4).

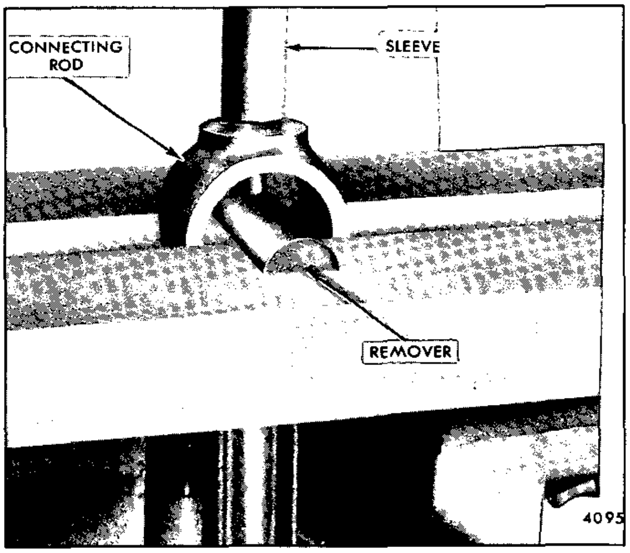


Fig. 5 – Removing Spray Nozzle

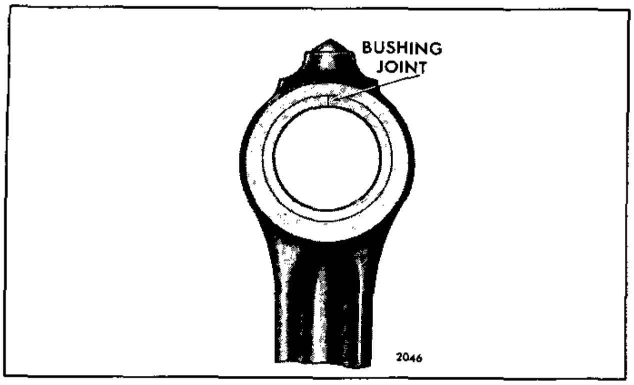


Fig. 6 – Location of Bushing Joint

2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig. 6).

3. Insert installer J 4972–2 in the bushing, then insert handle J 1513–2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.

4. Turn the connecting rod over in the holder and install the second bushing in the same manner.

5. The bushings must withstand an end load of 2,000 pounds without moving after installation.

6. Ream the bushings to size as follows:

   a. Clamp reaming fixture J 7608–4 in a bench vise.

   b. Slide sleeve J 7608–5 on the arbor of the fixture (for V–type engine connecting rod).

   c. Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig. 7). Tighten the nuts on the 3/8″–24 bolts (In–line and V–type engines) to 40–45 lb–ft (54–61 N·m) torque. Tighten the nuts on the 5/16″–24 bolts (early 6V engines) to 24–28 lb–ft (33–38 N·m) torque.

   d. Slide the front guide bushing J 4971–6 (with the pin end facing out) in the fixture.

   e. Install spacer J 7608–3 in the fixture.

   f. Align the upper end of the connecting rod with the hole in the reaming fixture.

   g. Install the rear guide bushing J 1686–5 on the reamer J 7608–21, then slide the reamer and bushing into the fixture.

   h. *Turn the reamer in a clockwise direction only,* when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

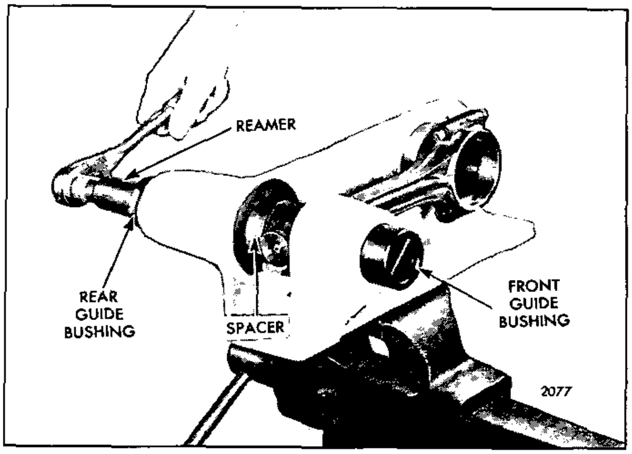


Fig. 7 – Reaming Bushings

NOTICE: Do not at any time turn the reamer counterclockwise as this will dull the cutting edges of the reamer.

   i. Remove the reamer and the connecting rod from the fixture, blow out the chips and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.3760″ to 1.3765″. This will provide a piston pin–to–bushing clearance of .0010″ to .0019″ with a new piston pin. A new piston pin has a diameter of 1.3746″ to 1.3750″. On the 6V–53T *the inside diameter of the bushings must be* 1.5025″ to 1.5030″. This will provide a piston pin–to–bushing clearance of .0025″ to .0034″ with a new piston pin. A new piston pin has a diameter of 1.4996″ to 1.5000″.

Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig. 2 and assemble the connecting rod to the piston as follows:

1. Place the "N/A" piston in the holding fixture (Fig. 8).

2. Place a new piston pin retainer in position. Then, place *the crowned end of installer J 23762–A against the* retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the "N/A" piston.

   If you have a turbo–trunk type piston, use tool J 24107–01 to seat the piston pin retainer. Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

3. Place the upper end of the connecting rod between the *piston pin bosses and in line with the piston pin holes.* Then, slide the piston pin in place. If the piston pin–to–bushing clearances are within the specified limits, the pin will slip into place without use of force.

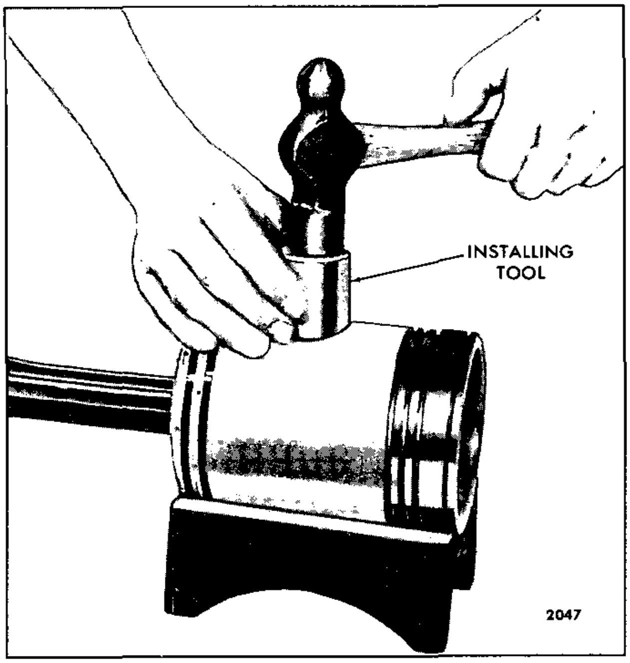


Fig. 8 – Installing Piston Pin Retainer Using Holder J 1513-02

4. Install the second piston pin retainer as outlined in Steps 1 and 2.

5. After the piston pin retainers have been installed, check for piston pin end clearance by *cocking* the connecting rod and shifting the pin in its bushings.

6. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987-01 (Fig. 9). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

7. Install the piston rings on the piston, as outlined in Section 1.6.

8. Install the piston and connecting rod assembly in the engine, as outlined in Section 1.6.3.

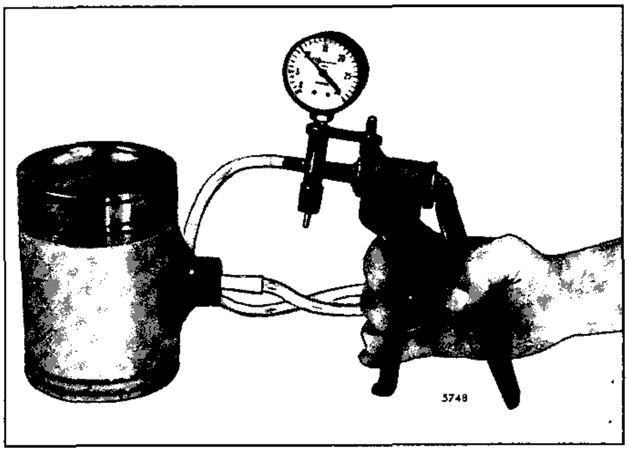


Fig. 9 – Checking Piston Pin Retainer for Proper Sealing Using Tool J 23987-01

CROSS-HEAD TYPE PISTON

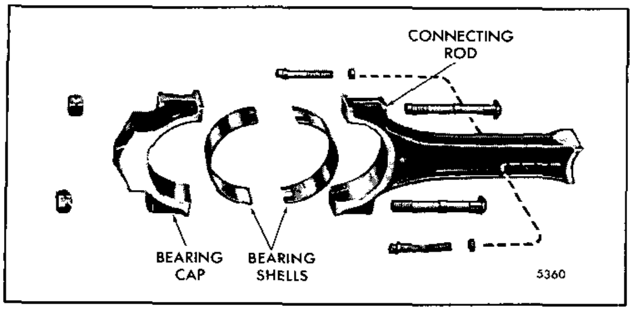


Fig. 10 – Connecting Rod Details

The connecting rod is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end (Fig. 10). The bearing cap and connecting rod are forged in one piece and bored prior to separation.

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two bolts and spacers. The bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a drilled oil passage in the connecting rod to the piston pin and bushing.

A service connecting rod includes the bearing cap and the attaching bolts and nuts. The replaceable connecting rod bearing shells are covered in Section 1.6.2.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod, as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with a suitable solvent and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Blow compressed air through the oil passage in the connecting rod to be sure it is clear of obstructions. Use crocus cloth, wet with fuel oil, to remove any trace of fretting and/or corrosion on the connecting rod saddle and piston pin contact surface with the rod before reassembly. Never use crocus cloth on the bearing side of the pin.

Connecting rods being removed from an original build engine can be reused as is, after considering the following:

1. Check for visual damage (bent).
2. A previous bearing(s) or related failure.
3. The connecting rod is blue at the top or bottom end.
4. Fretting at split line between the connecting rod and cap.
5. Excessive pound–in of the bolt head or nut.

If the connecting rod has been subjected to any of the above, it should be scrapped.

In qualifying a used connecting rod from a source other than an original build engine, the following checks should be made in addition to the above.

1. Check for cracks (Fig. 11) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*
2. Determine average bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 15):
   - a. Install the connecting rod cap on the connecting rod and tighten the bolt nuts to 40–45 lb ft (54–61 N·m) torque.

   NOTICE: Do not overtorque the connecting rod bolt nuts. Overtorque may permanently distort the connecting rod cap and result in bolt and/or nut damage.

   b. Measure diameter A and B (Fig. 12).

   c. Obtain the average of A and B to obtain size at split line.

   $$\frac{A + B}{2} = X \text{ — which is the average of } A + B.$$

   d. Measure C. The difference in the results of the measurements X and C gives average bore out–of–round and can be .005" maximum.

   e. Add C with X and average to obtain average bore size.

   $$\frac{C + X}{2} = \text{Average diameter of bore.}$$

   Must be within 2.7515" to 2.7525" (In–line) or 3.0015" to 3.0025" (V–type) engines.

If the crosshead connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

3. Determine taper as follows (Fig. 12):

   a. Substract D1 from D2 to find the difference.

   b. The difference can be .0005" maximum.

4. Determine length by finding the distance between E1 and E2 (Fig. 12).

   Specifications: 8.799" to 8.801".

   The length of the rod can be measured on connecting rod measurement fixtures marketed by B. K. Sweeney, Tobin Arp or equivalent.

Remove any nicks or burrs from the connecting rod bolt holes to ensure proper seating of the underside of the bolt head.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

NOTICE: Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Inspect the bearing (bushing) for indications of scoring, overheating or other damage. Measure the thickness of the bushing along the center. Replace the bushing if it is damaged or worn to a thickness of .085" or less. A new bushing is .086" to .087" thick.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 1.3746" to 1.3750". Replace the piston pin if it is worn to a diameter of 1.3730" or less.

Assemble Connecting Rod to Piston

Refer to *Assemble Piston* in Section 1.6 for assembly of the connecting rod to the piston.

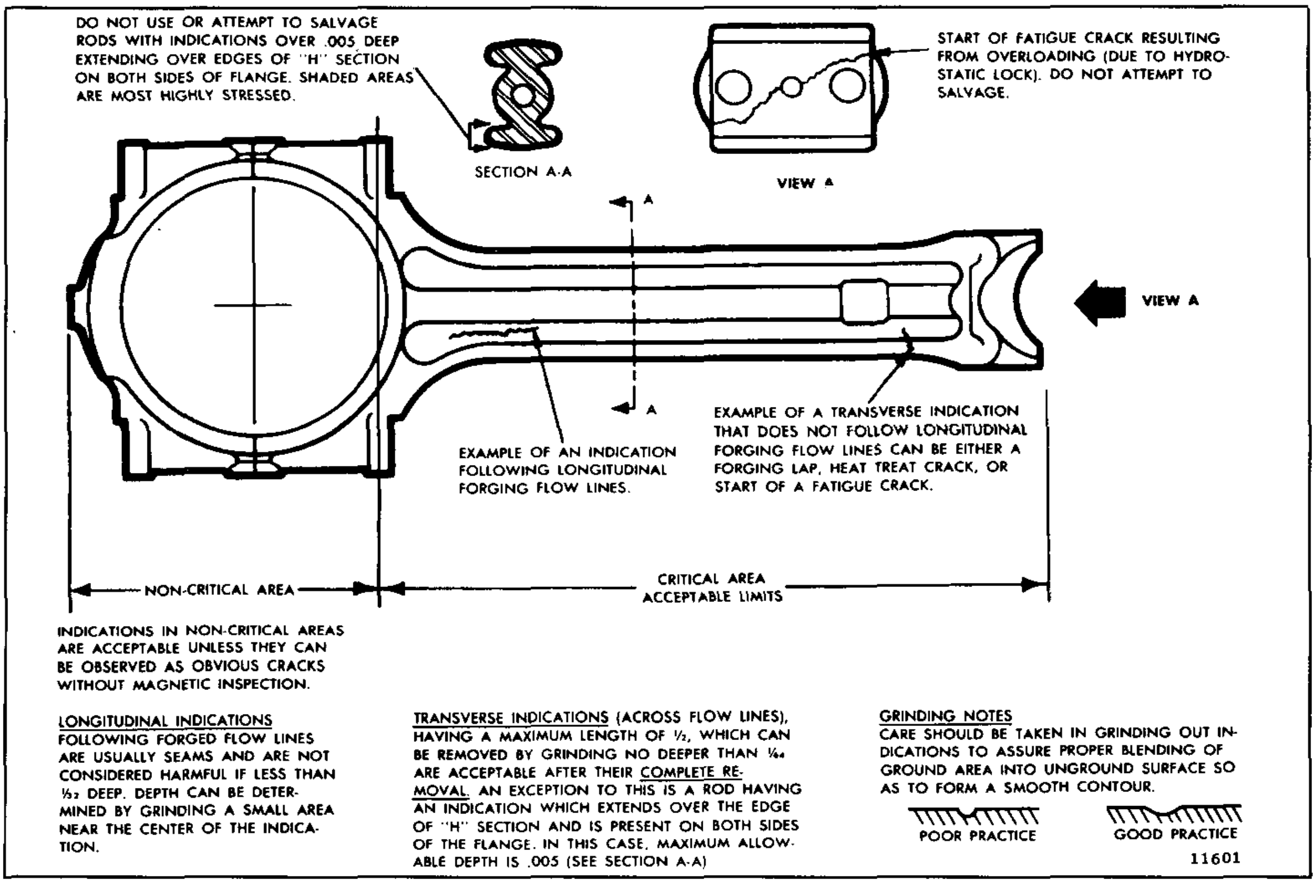


Fig. 11 – Magnetic Particle Inspection Limits for Connecting Rod

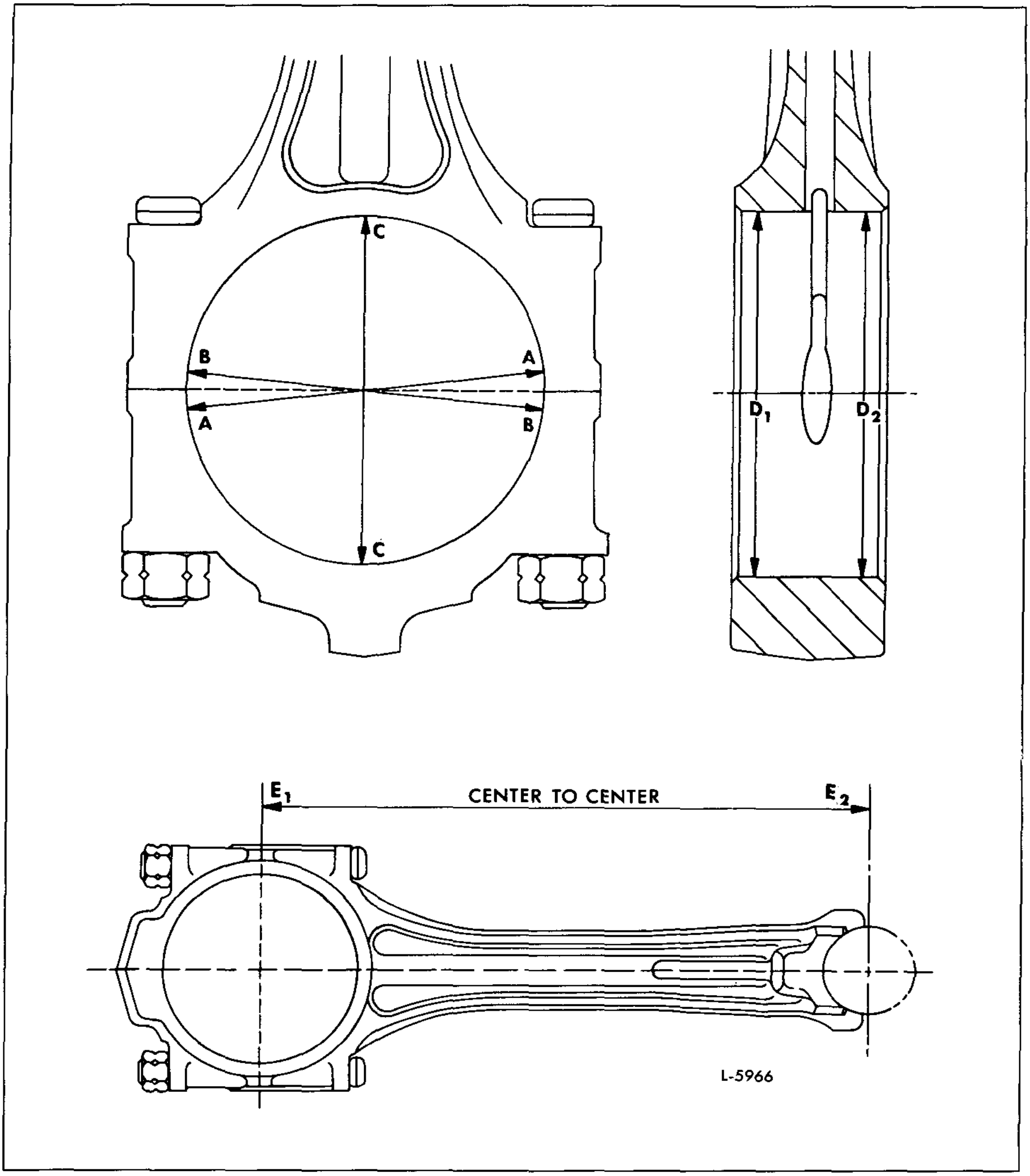


Fig. 12 – Dimensional Inspection of Cross-Head Piston Connecting Rods

CONNECTING ROD BEARINGS

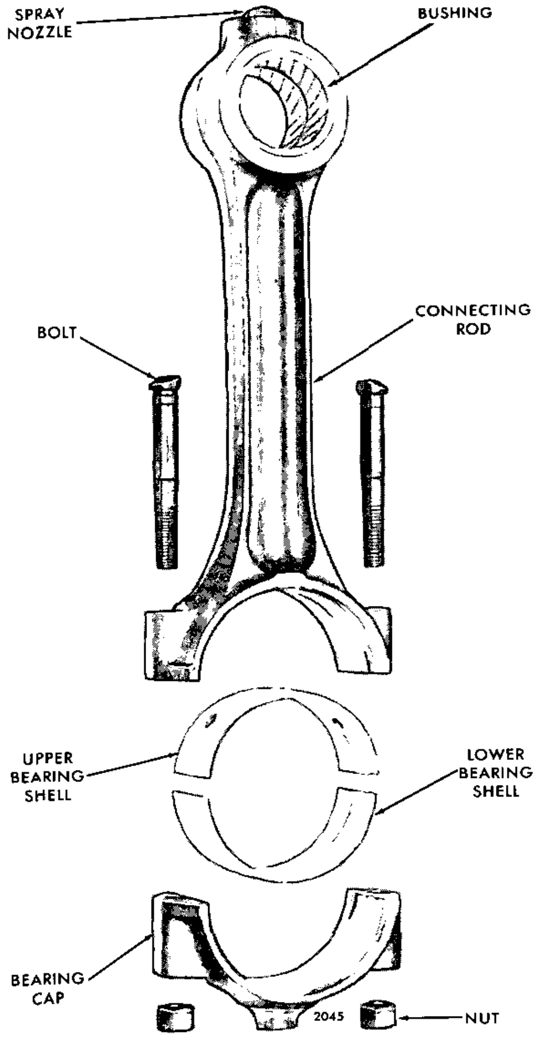


Fig. 1 – Connecting Rod and Bearing Shells

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The upper and lower bearing shells are located in the connecting rod by a tang at the parting line at one end of each bearing shell. The current connecting rod bearing shells used in the V–type engines incorporate a relief groove at each end of each bearing shell to provide clearance for the 3/8" connecting rod bolts.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell has two short oil grooves and two oil holes; each groove begins at the end of the bearing shell and terminates at an oil hole. The lower bearing shell has a continuous oil groove from one end of the shell to the other. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

The Brazilian built engine connecting rod bearings include a slotted upper shell.

Remove Bearing Shells

The connecting rod bearing caps are numbered 1, 2, 3, etc. on an In–line engine and 1R, 1L, 2R, 2L, etc. on the V–type engine, with matching numbers stamped on the connecting rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearings, as follows:

1. Drain the oil and remove the oil pan.
2. Remove the oil inlet pipe and screen assembly.

   NOTICE: Remove the oil pump on 8V engines and save the shims, if used, so that they may be reinstalled in exactly the same location.

3. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.
4. Inspect the upper and lower bearing shells as outlined under *Inspection.*
5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching or signs of overheating.

If any of these defects are present, the bearings must be discarded. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also, inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under *Inspection* in Section 1.3.4. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1230" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (In–line engine) or .1247" to .1252" (V–engine). Refer to Table 1.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). The maximum connecting rod bearing–to–journal clearance with used parts is .006".

Before installing the bearings, inspect the crankshaft journals (refer to *Inspection* in Section 1.3).

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
V-Type Engines		
Standard	.1247"/.1252"	.1230"
.002" Undersize	.1257"/.1262"	.1240"
.010" Undersize	.1297"/.1302"	.1280"
.020" Undersize	.1347"/.1352"	.1330"
.030" Undersize	.1397"/.1402"	.1380"

*Thickness 90° from parting line of bearing.

TABLE 1

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3.

Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

NOTICE: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, install the connecting rod bearings as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.
2. *Install the upper bearing shell — the one with the short* groove and oil hole at each parting line — in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.
3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.
4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell — the one with the continuous oil groove — in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.
5. Install the bearing and cap and tighten the nuts on the 3/8"–24 bolts (In–line and "V" engines) to 40–45 lb–ft (54–61 N·m) torque. Tighten the nuts on the former 5/16"–24 bolts (6V engine) to 24–28 lb–ft (33–38 N·m) torque. *Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.*
6. Install the lubricating oil pump inlet tube assembly. Replace the inlet tube seal ring or elbow gasket if hardened or broken.

   NOTICE: On the 8V engine, if shims were used between the oil pump body and the main bearing caps, install the shims in exactly the same location from which they were removed.
7. Install the oil pan, using a new gasket.
8. Refer to the *Lubrication Specifications* in Section 13.3 and fill the crankcase to the proper level on the dipstick.
9. If new bearings were installed, operate the engine on the *run–in* schedule, as outlined in Section 13.2.1.

CYLINDER LINER

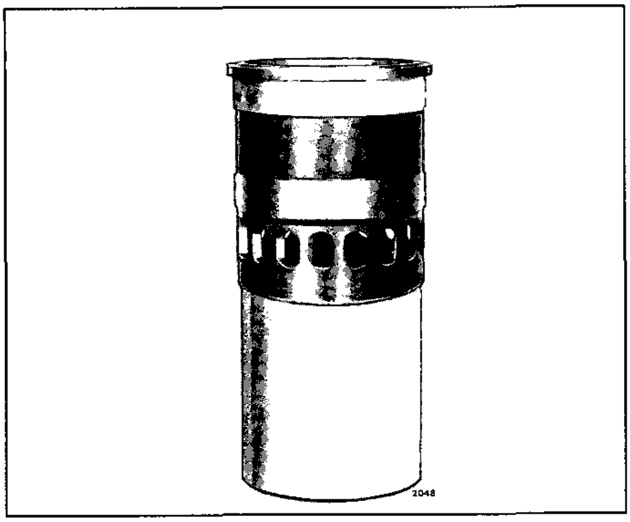


Fig. 1 – Cylinder Liner

The cylinder liner (Fig. 1) is of the replaceable wet type, made of hardened alloy cast iron, and is a slip fit in the cylinder block. The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner rests on a counterbore in the top of the block.

Two silicone seal rings, recessed in the cylinder block bore, is used between the liner and the block to prevent water leakage into the air box.

The upper portion of the liner is directly cooled by water surrounding the liner. The center portion of the liner is air cooled by the scavenging air which enters the cylinder through equally spaced ports. On 6V (aluminum) and 8V engines, the lower portion of the liner is cooled by water inside the cylinder block water–jacket surrounding the liner. However, regardless of the type of cooling, the current cylinder liner is applicable to all engines except those with cross–head pistons.

- New cross–head pistons and rings, connecting rods, and cylinder liners became standard in all turbocharged industrial engines equipped with bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545

The port height of the new liner is smaller (.740 vs .840) to provide optimum air swirl in the combustion chamber. The new liner is also identified by a 3/16" wide machined groove below the liner ports.

> **NOTICE:** Do not mix trunk style pistons and cross–head pistons in the same engine. The difference in weight will affect engine balance. Failure to observe this precaution can result in serious engine damage.

When rebuilding a turbocharged engine with cross–head pistons, always make sure that the correct cylinder liner is installed. The cross–head piston liner has a .74" port height, while the standard liner has a .84" port height. If the standard liner is installed in place of the cross–head piston liner, a small loss in power and an increase in smoke will result.

The .74" port height liner can be identified as follows:

1. The part number is stamped on the outside diameter of the liner.
2. The liner has an identification groove machined around the outside diameter surface just below the ports.

The air inlet ports in the liner are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion. The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. *Do not* attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft, otherwise the piston may be damaged or the upper ring groove may collapse.

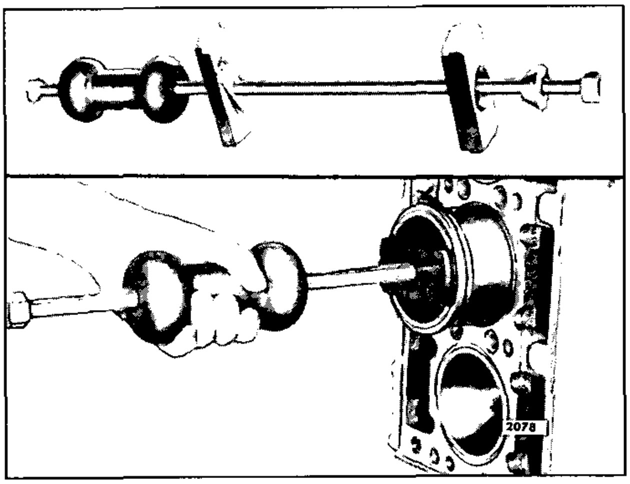


Fig. 2 – Removing Cylinder Liner with Tool J 22490

To remove a cylinder liner, refer to Fig. 2 and proceed as follows:

1. Remove the piston and connecting rod assembly as outlined in Section 1.6.

2. Remove the cylinder liner with tool set J 22490 as follows:

   a. Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then, slide the upper puller clamp down against the top edge of the liner.

   b. With the tool in place, strike the upset head on the upper end of the puller rod a sharp blow with the puller weight, thus releasing the liner.

   c. Remove the tool from the liner. Then, remove the liner from the cylinder block.

   d. Remove and discard the cylinder liner seal ring from the groove in the cylinder block bore.

NOTICE: After removing liners from an engine and prior to installing liners, always store them in an upright position until ready for use. Liners left on their side for any length of time can become egg-shaped and distorted, making installation in cylinder bores difficult or impossible.

If tool J 22490 is unavailable, tap the liner out with a hardwood block and hammer.

Inspect Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

- Cracks
- Scoring
- Poor contact on outer surface
- Flange irregularities
- Inside diameter
- Outside diameter
- Out–of–round
- Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned–up and reused.

When removing the preservative from new liners, do not steam–clean. Instead, stand the liners upright in a metal basket and immerse in a suitable cold tank containing pure mineral spirits or fuel oil. Steam cleaning may cause internal engine parts to water spot and corrode. Placing liners on their sides for cleaning can lead to liner distortion.

Excessive liner–to–block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant.

Examine the outside diameter of the liner for fretting below the ports. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

Measure the block bore (Section 1.1) and the outside diameter of the liner (refer to Section 1.0 for Specifications).

A new .020" oversize O.D. cylinder liner has been released to service Series 53 engines. To ensure serviceability, a new liner–to–block seal ring (identified by two yellow stripes) has also been released for use with the new liner. The standard seal ring has no paint identification and is used only with standard and .010" oversize O.D. liners. These are available for both standard and short port liner replacement.

Do not modify the surface finish in a new service cylinder liner. Since the liner is properly finished at the factory, any change will adversely affect seating of the piston rings.

A used cylinder liner must be honed for the following reasons:

1. To break the glaze (Fig. 3) due to the rubbing action of the piston rings after long periods of operation. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

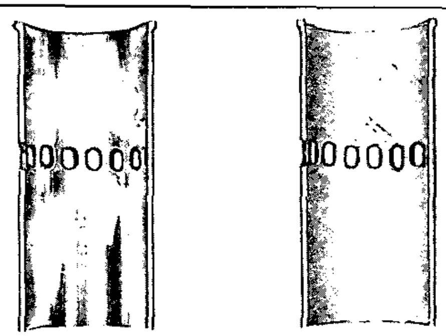


Fig. 3 – Glazed Surface of Cylinder Liner

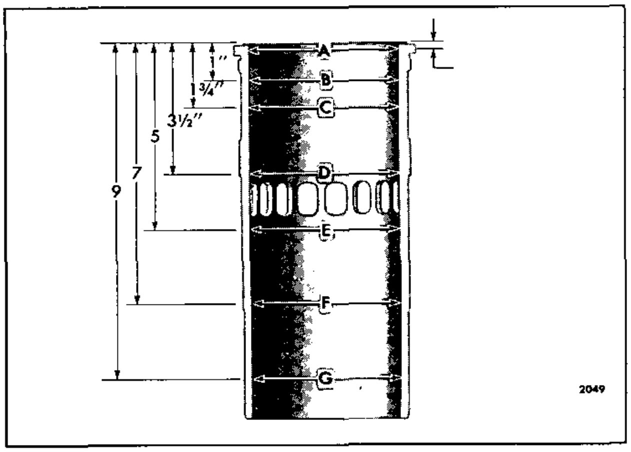


Fig. 4 – Cylinder Liner Ridge Due to Wear

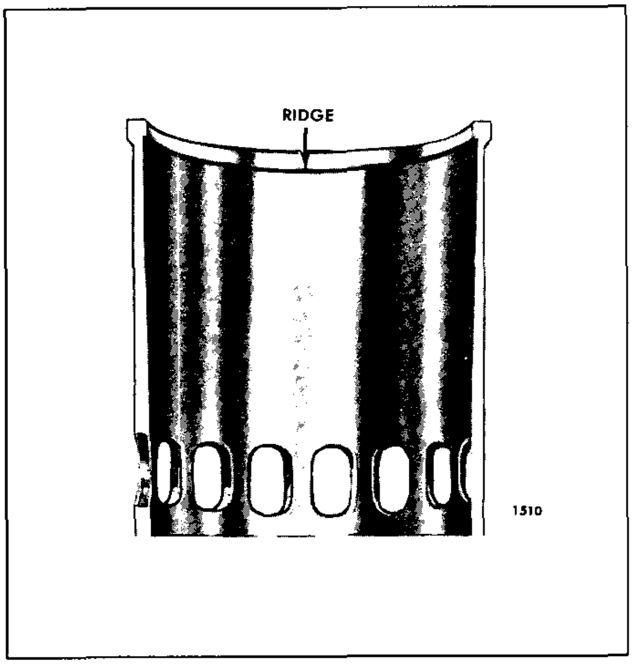


Fig. 5 – Cylinder Liner Measurement Diagram

2. To remove the ridge (Fig. 4) formed at the top by the piston ring travel. Otherwise, interference with the travel of the new compression rings may result in ring breakage.

Therefore, even though the taper and out–of–round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902–01, equipped with 120 grit stones J 5902–14, should be worked up and down (at 300–400 rpm) the full length of the liner a few times in a criss–cross pattern that produces hone marks on the 45° axis.

After the liner has been honed, remove it from the fixture and clean it thoroughly. Then, dry it with compressed air and check the entire surface for burrs.

After honing, the liner must conform to the same limits on taper and out–of–round as a new liner and the piston–to–liner clearance must be within the specified limits (Section 1.0).

Install the liner (new or used) in the proper bore of the cylinder block and measure the inside diameter at the various points shown in Fig. 5. Use cylinder bore gage J 5347–B (Fig. 6), which has a dial indicator calibrated in .0001" increments. Set the cylinder bore gage on zero in master ring gage J 8385–01. Also, check the liner for taper and out–of–round. Dial bore gage master setting fixture J 23059–01 may be used in place of the master ring gage.

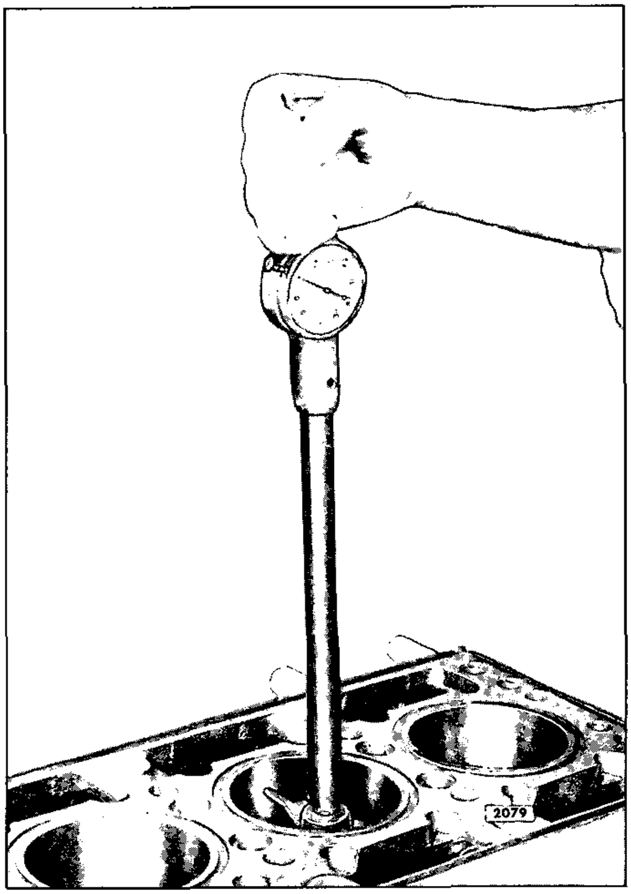


Fig. 6 – Checking Bore of Cylinder Liner Using Tool J 5347–B

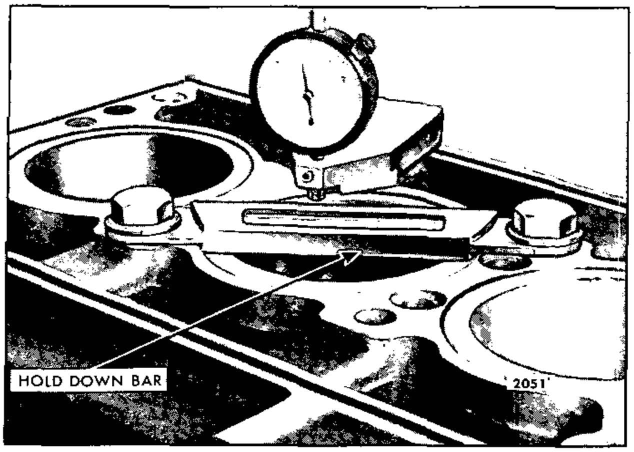


Fig. 7 – Checking Distance of Liner Flange Below Top Face of Block Using J 22273-01 and Hold-Down Tool J 21793-B

The piston–liner clearance must be within the specified limits (Section 1.0). Also, the taper must not exceed .002″ and the out–of–round must not exceed .003″ on a used liner. The taper must not exceed .001″ and the out–of–round must not exceed .002″ on a new liner.

New service liners have an *inside* diameter of 3.8752″ to 3.8767″.

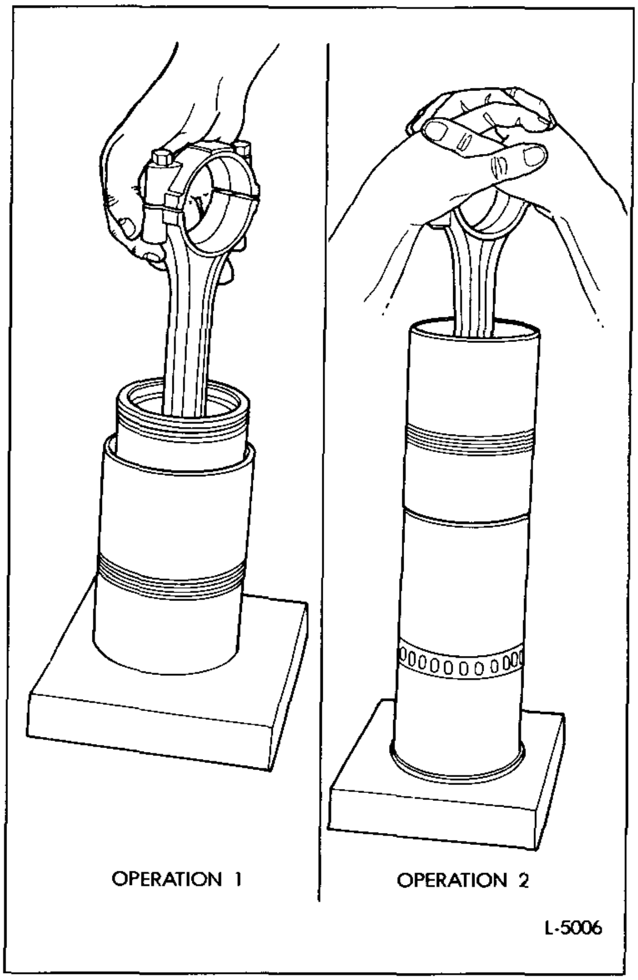
Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean.
2. Slide the liner into the block until the flange rests on the bottom of the counterbore in the block. Do not drop or slam the liner flange against the bottom of the counterbore in the block.
3. Tap the liner lightly with a soft hammer to make certain the liner flange seats on the bottom of the counterbore.
4. Install a cylinder liner hold–down clamp as illustrated in Fig. 7.
5. Measure the distance from the top of the liner flange to the top of the block with a dial indicator (Fig. 7). The liner flange must be .0465″ to .0500″ below the top of the block. However, even though all of the liners are within these specifications, there must not be over .002″ difference between any two adjacent liners when measured along the cylinder longitudinal center line. If the above limits are not met, install the liner in another bore and recheck, or use a new liner.
6. Matchmark the liner and the cylinder block with a felt pen so the liner may be reinstalled in the same position in the same block bore. Place the matchmarks on the engine serial number side of the block (In–line engine) or on the outer edge of the block (V–type engine).
7. Remove the hold–down clamp and the cylinder liner.

Install Piston and Connecting Rod Assembly

1. With the piston assembled to the connecting rod and the piston rings in place as outlined in Sections 1.6 and 1.6.1, apply clean engine oil to the piston, rings and the inside surface of the piston ring compressor J 6883–01.

NOTICE: Inspect the ring compressor for nicks or burrs, especially at the non–tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.



• Fig. 8 – Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

2. Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.

3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring compressor. Then, push the piston down until it contacts the wood block ("Operation 1" of Fig. 8).

5. Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner ("Operation 2" of Fig. 8). The numbers, or number and letter, on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers, or number and letter, must be stamped in the same location as on the connecting rod that was replaced.

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor (operation 2 of Fig. 8).

- **CAUTION: To avoid scraping knuckles or pinching fingers between the rod end and ring compressor walls, interlock fingers and place hands as shown (operation 2) when pushing down. This keeps fingers out of the installer when the piston slides into the liner.**

  NOTICE: Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then, push the piston down until the compression rings pass the cylinder liner ports.

Install Cylinder Liner, Piston and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

1. Make sure the seal ring grooves in the cylinder block bore are clean. Then, install two new seal rings (Fig. 9).

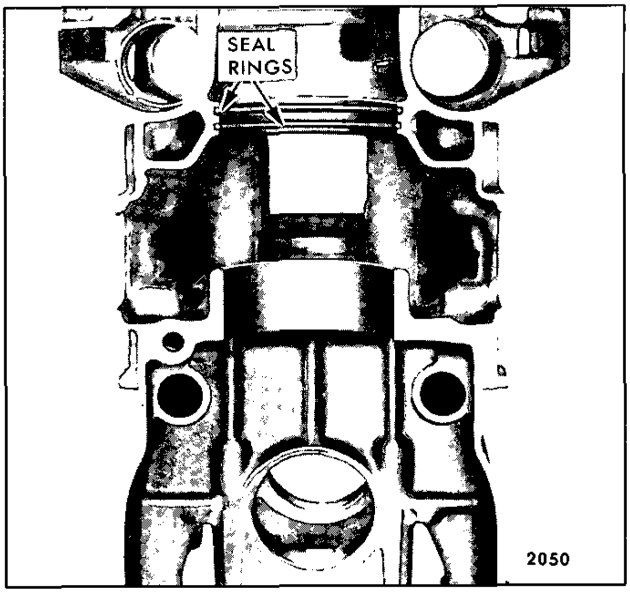


Fig. 9 – Cylinder Liner Seal Ring Location in Cylinder Block Bore

2. Apply hydrogenated vegetable type shortening or ethylene glycol base antifreeze to the inner surface of the seal rings.

3. If any of the pistons and liners are already in the engine, use hold–down clamps to retain the liners in place when the crankshaft is rotated.

4. Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

5. Install the upper bearing shell — the one with a short oil groove at each parting line — in the connecting rod. Lubricate the bearing shell with clean engine oil.

6. Position the piston, rod and liner assembly in line with the block bore (Fig. 10) so that the identification number on the rod is facing the outer edge of the block (V–type engine) or the engine serial number side (In–line engine). Also, align the matchmarks on the liner and the block. Then, slide the entire assembly into the block bore being careful not to damage the seal rings.

7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

   NOTICE: On a V–type engine, the distance from the center of the connecting rod bolts to the sides of the rod are not equal. Therefore, to avoid cocking the rods, the narrow sides of the rods must be together when attached to the crankshaft.

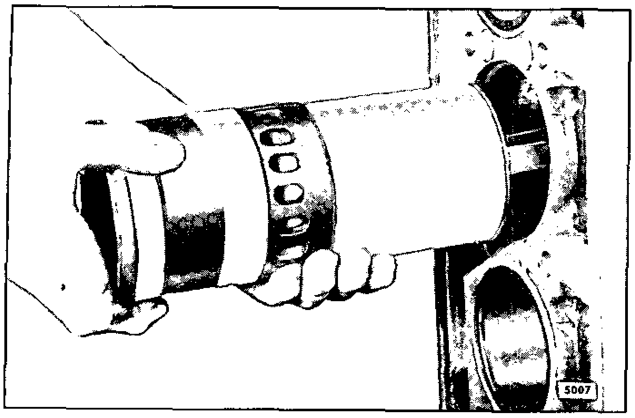


Fig. 10 – Installing Piston, Rod and Liner Assembly in Cylinder Block

8. Place the lower bearing shell — the one with the continuous oil groove from one parting line to the other — in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

9. Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. On the 3/8″–24 bolts (In–line and "V" engines), tighten the nuts to 40–45 lb–ft (54–61 N·m) torque. Tighten the nuts on the 5/16″–24 bolts (early 6V engines) to 24–28 lb–ft (33–38 N·m) torque. Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut. The new 6V rod assembly with 3/8″ bolts should be used for replacement at the time of normal overhaul. Rework of an old 6V rod assembly to utilize 3/8″ bolts is not recommended.

10. Check the connecting rod side clearance. The clearance between the side of the rod and the crankshaft should be .006″ to .012″ with new parts on an In–line engine or .008″ to .016″ clearance between the connecting rods on a V–type engine.

11. Install the remaining liner, piston and rod assemblies in the same manner. Use hold–down clamps to hold each liner in place.

12. After all of the liners and pistons have been installed, remove the hold–down clamps.

13. Install new compression gaskets and water and oil seals as outlined in Section 1.2. Then, install the cylinder head and any other parts which were removed from the engine.

14. After the engine has been completely reassembled, refer to the *Lubrication Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

15. Close all of the drains and fill the cooling system.

16. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the *run–in* schedule given in Section 13.2.1.

ENGINE BALANCE AND BALANCE WEIGHTS

In the balance of two–cycle engines, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds: unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft. On a V–type engine, this unbalanced couple tends to move the ends of the engine in an elliptical path; on an In–line engine, it tends to rock the engine from end to end in a vertical plane. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the camshafts (V–type engine) or at the outer ends of the balance shaft and camshaft (In–line engine). This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

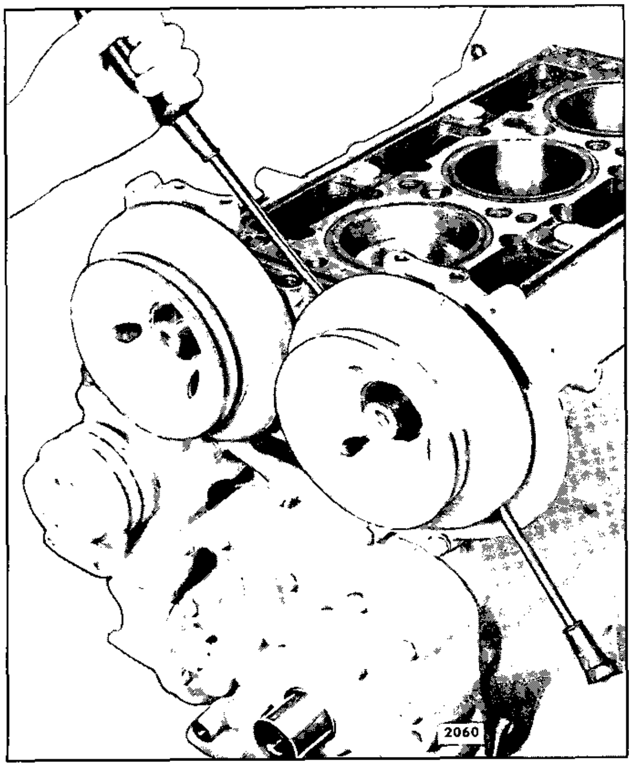


Fig. 1 – Removing Front Balance Weight (Pulley Type)

On the camshafts (V–type engine) or balance shaft and camshaft (In–line engine), each set of weights (weights on the outer ends of each shaft comprise a set) rotates in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights; therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

The balance weights are integral with the gears and the circular balance weights (pulleys) on the shafts. Additional weights are attached to the camshaft and balance shaft gears on two, three and four cylinder engines.

Both the rotating and primary reciprocating forces and couples are completely balanced in the engines. Consequently, the engines will operate smoothly and in balance throughout their entire speed range.

Effective with engine serial numbers 3D–193526, 4D–209292 and 6D–229545 new camshaft front pulleys and weights are used with new bolt–on balance weights which are attached to the rear camshaft gears. When replacing the trunk type pistons with cross–head type pistons in an engine, the new camshaft front pulleys and heavier weights must be used.

When the cross–head pistons are to be installed in an engine built prior to serial numbers 3D–193526, 4D–209292 or 6D–229545, and an in–frame overhaul is desired, a new bolt–on rear balance weight must be used in addition to the existing balance weight attached to the flywheel housing side of each rear camshaft gear. Refer to Section 1.0 for the installation procedure.

Remove Front Balance Weights

1. Remove the nut at each end of both shafts as outlined in Section 1.7.2.

2. Force the balance weight off the end of each shaft, using two screw drivers or pry bars between the balance weight and the upper front cover (Fig. 1).

Install Front Balance Weights

1. Reinstall the Woodruff keys in the shafts, if they were removed.

2. Align the keyway in the balance weight with the key in the shaft, then slide the weight on the shaft. If the weight does not slide easily onto the shaft, loosen the thrust washer retaining bolts at the opposite end of the shaft. Then, to prevent possible damage to the thrust washer, support the rear end of the shaft while tapping the weight into place with a hammer and a sleeve. Retighten the thrust washer retaining bolts to 30–35 lb–ft (41–47 N·m) torque. Install the other weight in the same manner.

3. Wedge a clean rag between the gears. Refer to Section 1.7.2 and tighten the gear retaining nuts to 300–325 lb–ft (407–441 N·m) torque. Then, tighten the front balance weight retaining nuts to 300–325 lb–ft (407–441 N·m) torque. Remove the rag from the gears.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the Series 53 engine.

The gear train on an In–line engine consists of a crankshaft gear, an idler gear, a camshaft gear and a balance shaft gear (Fig. 1). The governor drive gear, the upper blower rotor gear for the two and three cylinder engines, and the blower drive gear for the four cylinder engine are driven by the camshaft gear or balance shaft gear, depending upon the engine model.

The gear train on a 6V engine (Fig. 2) or an 8V engine (Fig. 3) consists of a crankshaft gear, an idler gear and two camshaft gears. The accessory drive (fuel pump drive — Section 2.2.1) gear is driven by a camshaft gear.

To reduce the level of engine noise in the Series 53 engines, the pitch and pressure angle of the gear train and accessory drive gears has been changed. This is effective with engine serial numbers 3D–170683, 4D–180939 and 6D–196535.

This reduction in noise level has been accomplished by changing the gear pitch from 14 to 16 and the pressure angle from 20° to 16°. Identification of the new and former gears can be made by counting the number of teeth in the gears (Table 1).

The former individual 20° angle main gear train gears (crankshaft, idler, balance and camshaft gears) will be available for service until stock is exhausted. Then, when any one gear requires replacement, all of the gears in the gear train must be changed to the 16° angle gears. The former governor, fuel pump, blower rotor and blower drive gears will continue to be serviced, as well as the new gears.

On In–line and 6V engines, the crankshaft gear is pressed on and keyed to the end of the crankshaft. On 8V engines, the crankshaft gear is keyed and bolted to the end of the crankshaft.

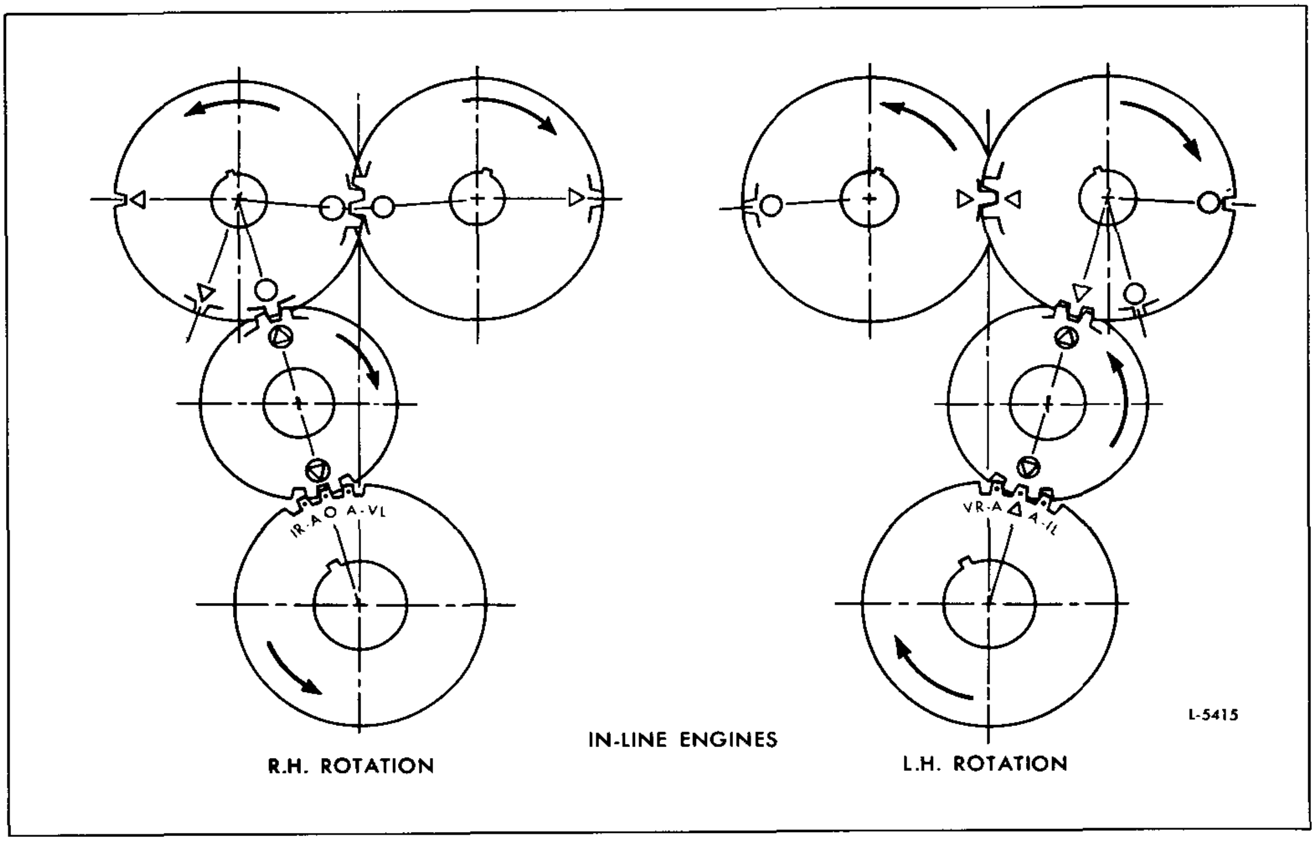


Fig. 1 – In–Line Engine Gear Train Timing Mark (Standard Timing Shown)

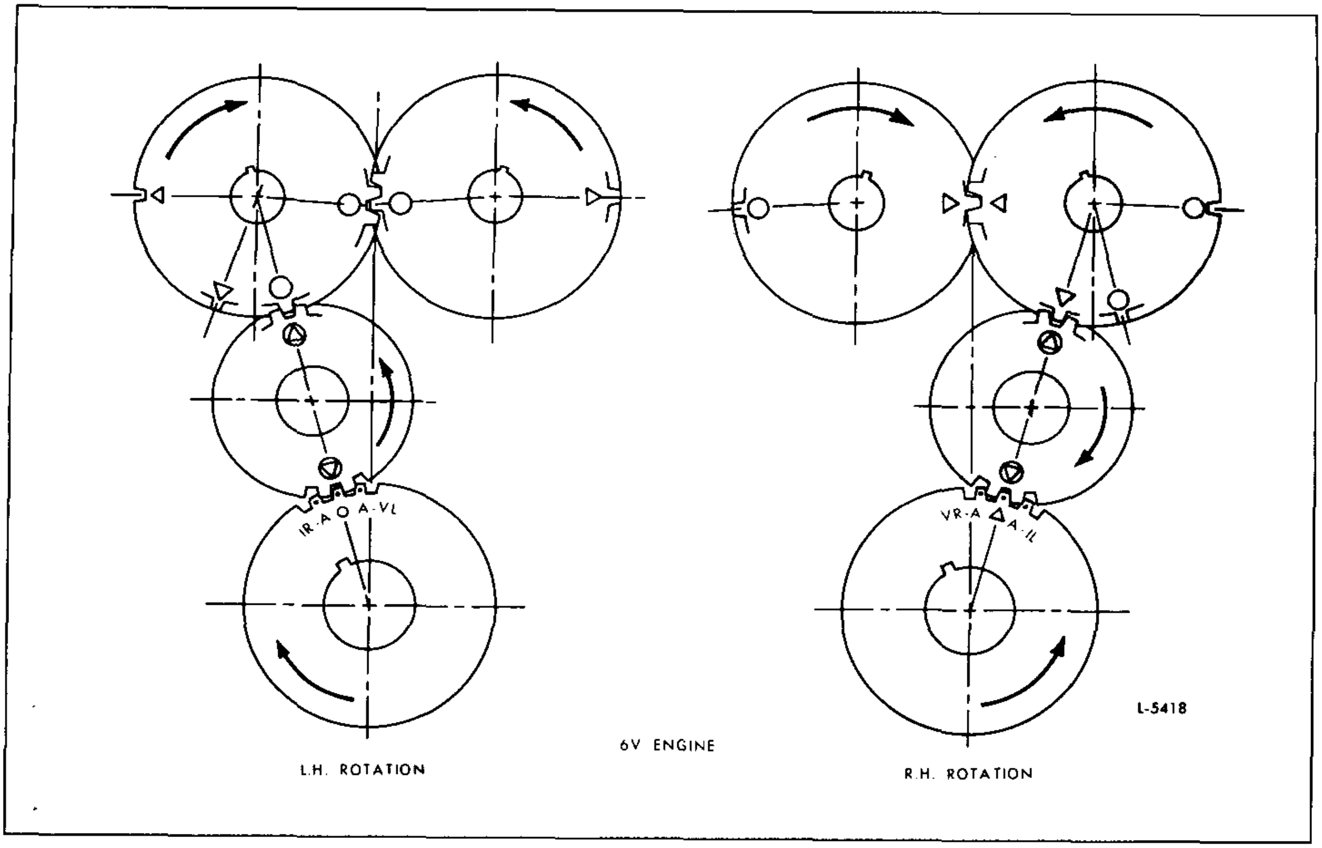


Fig. 2 – 6V Engine Gear Train Timing Marks (Standard Timing Shown)

Gear	Number of Teeth	
	Former	New
Crankshaft	97	111
Balance and Cam	97	111
Idler	72	82
Blower Drive	39	45
Blower Rotor	39	45
Governor Drive	49	56
Fuel Pump Drive	49	56

TABLE 1

The idler gear rotates on a stationary hub.

The camshaft and balance shaft gears on In–line engines and the camshaft gears on 6V and 8V engines are pressed on and keyed to their respective shafts and each gear is secured by a retaining nut and lock plate.

The crankshaft, idler, camshaft and balance shaft gears on In–line and 6V engines are completely interchangeable with each other. However the 8V crankshaft gear, idler gear and camshaft gears are not interchangeable with the In–line and 6V engine gears.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3–53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D–193516 and 6D–229616.

On In–line engines, the camshaft and balance shaft gears have additional weights attached to the rear face of each gear. Different size weights are used on the three and four cylinder engines. These weights are important in maintaining perfect engine balance. Additional balance weights are not required on 6V camshaft gears. On early 8V engines, the camshaft gears have additional weights attached to the rear face of each gear. On current 8V engines, additional balance weights are not required.

The camshaft and balance shaft gears on an In–line engine, and the two camshaft gears on 6V and 8V engines, mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft gears must be in time with each other, and the two as a unit in time with the crankshaft gear, timing marks have been stamped on the face of the gears to facilitate correct gear train timing.

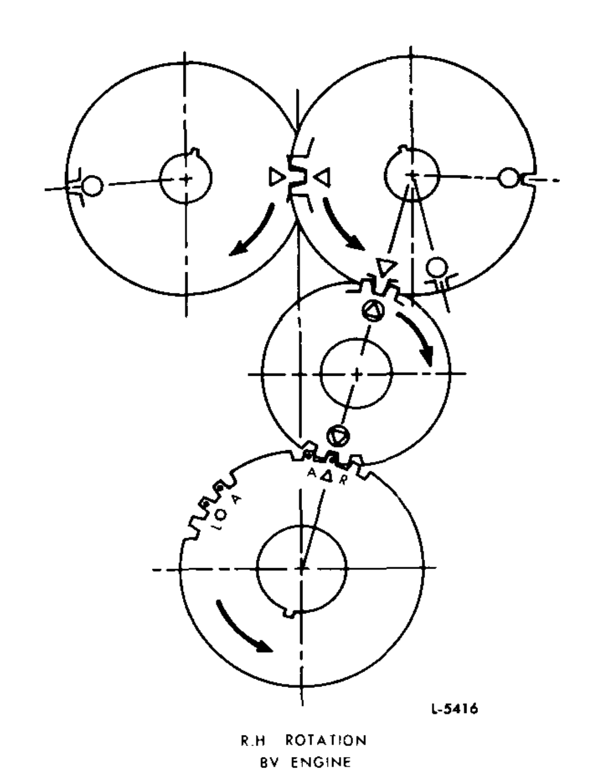


Fig. 3 – 8V Engine Gear Train Timing Marks (Standard Timing Shown)

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the camshaft and/or balance shaft gear in that order, line up the appropriate circle symbols on the gears or the appropriate triangles as each gear assembly is installed on the engine. Refer to Figs. 1, 2 and 3 for a typical gear train timing arrangement.

It is advisable to make a sketch indicating the position of the timing marks *before* removing or replacing any of the gears in the gear train.

The circle and the triangle are the basic timing symbols stamped on the gears. The letters stamped on the crankshaft gears identify the proper timing marks for the particular engine: "I" represents "In–line" engine, "V" represents V–type engine, "R" represents right–hand rotation engine, "L" represents left–hand rotation engine and "A" represents advanced timing.

Effective with engine serial numbers 3D–64404, 4D–65954, 6D–66099 and 8D–3826, all Series 53 vehicle engines are built with advanced timing. The timing is advanced by aligning the proper "A" timing mark on the crankshaft gear with the circle–triangle timing mark on the idler gear.

IN–LINE ENGINE:

The camshaft and balance shaft gears are positioned so that the circle timing marks are adjacent to each other (Fig. 1). One circle–triangle timing mark on the idler gear is aligned with the second "circle" on the mating camshaft (or balance shaft) gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "IR–A" on the left side of the circle timing mark for a right–hand rotation engine (Fig. 1). For *standard timing,* the circle on the crankshaft gear is aligned with the circle–triangle on the idler gear. For *advanced timing,* the "A" adjacent to the "IR" on the crankshaft gear is aligned with the circle–triangle on the idler gear.

The crankshaft timing gear is stamped "A–IL" on the right side of the triangle timing mark (Fig. 1) for a left–hand rotation engine. For *standard timing,* the "triangle" on the crankshaft gear is aligned with the circle–triangle on the idler gear. For *advanced timing,* the "A" adjacent to the "IL" on the crankshaft gear is aligned with the circle–triangle on the idler gear.

6V ENGINE:

The camshaft gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 2). One circle–triangle timing mark on the idler gear is aligned with the second "triangle" on the mating camshaft gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "VR–A" on the left side of a triangle timing mark for a right–hand rotation engine (Fig. 2). For *standard timing,* the "triangle" on the crankshaft gear is aligned with the circle–triangle on the idler gear. For *advance timing,* the "A" adjacent to the "VR" on the crankshaft gear is aligned with the circle–triangle on the idler gear.

The crankshaft timing gear is stamped "A–VL" on the right side of a circle timing mark for a left–hand rotation engine (Fig. 2). For *standard timing,* the "circle" on the crankshaft gear is aligned with the circle–triangle on the idler gear. For *advanced timing,* the "A" adjacent to the "VL" on the crankshaft gear is aligned with the circle–triangle on the idler gear.

8V ENGINE:

The camshaft gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 3). One circle–triangle timing mark on the idler gear is aligned with

the second "triangle" on the mating camshaft gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "A–triangle–R". For *standard timing,* the triangle on the crankshaft gear is aligned with the circle–triangle on the idler gear. For *advanced timing,* the "A" on the crankshaft gear is aligned with the circle–triangle on the idler gear.

Refer to the *General Information* section for the various gear train arrangements.

There are no timing marks on the governor drive gear, blower rotor gears, blower drive gear or the accessory drive (fuel pump) gear. Therefore, it is not necessary to align these gears in any particular position when meshing the various gears with the camshaft or balance shaft gears.

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth or excessive bearing wear. Therefore, when noise develops in a gear train, remove the flywheel housing and inspect the gear train and its bearings. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

The backlash between the various mating gears in the gear train (former and current) should be .0005" to .005", except the blower rotor gears which should be .0005" to .0025". Maximum permissible backlash between worn blower gears is .0035" and should not exceed .007" clearance between all other gears in the gear train.

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of the oil also spills into the gear train compartment from the camshaft and balance shaft end bearings and the idler gear bearing. The blower drive gear bearing on the four cylinder In–line engine is lubricated through an external pipe leading from the cylinder block main oil gallery to the gear hub support. The idler gear bearing and the accessory (fuel pump) drive gear on the 6V or 8V engine is lubricated by oil directly from the cylinder block main oil gallery to the bearing hubs.

ENGINE TIMING

The correct relationship between the crankshaft and camshaft(s) must be maintained to properly control fuel injection and the opening and closing of the exhaust valves.

The crankshaft timing gear can be mounted in only one position since it is keyed to the crankshaft. The camshaft gear(s) can also be mounted in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the markings on the various gears will match (Figs. 1, 2 and 3).

Preignition, uneven running and a loss of power may result if an engine is "out of time".

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without removing the flywheel and flywheel housing by following the procedure outlined below.

Check Engine Timing

Access to the crankshaft pulley, to mark the top dead center position of the selected piston, and to the front end of the crankshaft or the flywheel for turning the crankshaft is necessary when performing the timing check. Then, proceed, as follows:

1. Clean and remove the valve rocker cover. Discard the gasket(s).
2. Select any cylinder for the timing check.
3. Remove the injector as outlined in Section 2.1 or 2.1.1.
4. Carefully slide a rod, approximately 12" long, through the injector tube until the end of the rod rests on top of the piston. Place the throttle in the *no–fuel* position. Then, turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
5. Select a dial indicator with .001" graduations and a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.
6. Mount the indicator over the injector tube. Check to be sure the indicator spindle extension is free in the injector tube and is free to travel at least one inch.
7. Attach a suitable pointer to the engine lower front cover. The outer end of the pointer should extend out over the top of the crankshaft pulley.
8. Turn the crankshaft slowly, in the direction of engine rotation, until the indicator hand just stops moving.

9. Continue to turn the crankshaft, in the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010".

10. Scribe a line on the crankshaft pulley in line with the end of the pointer.

11. Slowly turn the crankshaft, opposite the direction of rotation, until the indicator hand stops moving.

12. Continue to turn the crankshaft, opposite the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010".

13. Scribe the second line on the crankshaft pulley in line with the end of the pointer.

14. Scribe a third line on the pulley half way between the first two lines. This is top dead center.

If the crankshaft pulley retaining bolt loosened up, tighten it to the torque specified in Section 1.0.

15. Remove the dial indicator and rod from the engine.

16. Install the injector as outlined in Section 2.1 or 2.1.1. Then, refer to Section 14 and adjust the exhaust valve clearance and time the fuel injector.

17. Turn the crankshaft, in the direction of rotation, until the exhaust valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests on the top of the injector follower. Then, set the indicator on zero. Next turn the crankshaft slowly, in the direction of rotation, until the center mark on the pulley is in line with the pointer.

18. Check the front end of the camshaft for an identification mark. For identification purposes, a camshaft with no designation on the ends or a "7" stamped on the ends is a high-velocity high-lift camshaft. A camshaft metal stamped with a "V" or "V7" is a low-velocity high-lift camshaft. Effective with engines 4D-112278 and 6D-60777, new camshafts metal stamped "V7L" are used, intermittenly in the 4-53 and 6V engines. These are low velocity low-lift camshafts. Note the indicator reading and compare it with the dimensions listed in Table 2 for the particular camshaft in the engine.

19. Remove the dial indicator. Also, remove the pointer attached to the front of the engine.

20. Use new gasket(s) and install the valve rocker cover.

Engine	*INDICATOR READING		
	Correct	Retarded 1-Tooth	Advanced 1-Tooth
	STANDARD TIMING		
(1) 2,3,4 & 6V	.228"	.204"	.245"
(2) 3,4,6V & 8V	.206"	.179"	.232"
	ADVANCED TIMING		
(2) 3,4,6V & 8V	.232"	.206"	.258"

* Indicator readings shown are nominal values. The allowable tolerance is ± .005 in.
(1) High velocity type injector cam.
(2) Low velocity type injector cam.

TABLE 2

CAMSHAFT, BALANCE SHAFT AND BEARINGS

The camshaft and balance shaft used in the In–line engines, or the two camshafts used in the V–type engines, are located just below the top of the cylinder block. The camshaft and balance shaft in the In–line engines may be positioned on either side of the engine as required by the engine rotation and accessory arrangement. The camshafts in the V–type engine are positioned according to engine rotation.

The accurately ground cams ensure efficient, quiet cam follower roller action. They are also heat treated to provide a hard wear surface.

Both ends of the shafts are supported by bearings (bushing type) that are pressed into bores in the cylinder block. The balance shaft is supported by front and rear bearings only, whereas the camshaft is supported by end, intermediate and center bearings. Two end bearings (front and rear), two intermediate bearings and a center bearing are used in the 4–53 and 8V–53 engines to support the camshafts. The camshafts in the 3–53 and 6V–53 engine are supported by two end bearings and two intermediate bearings.

To facilitate assembly, letters signifying the engine models in which a shaft may be used are metal stamped on the ends of the shaft. The letters on the timing gear end of the camshaft must correspond with the engine model. For example, the letters RC are stamped on a camshaft used in an RC model engine. For additional identification, a camshaft with no designation on the ends or a "7" stamped on the ends is a high–velocity high–lift camshaft. A camshaft metal stamped with a "V" or "V7" is a low–velocity high–lift camshaft. Effective with engines 4D–112278 and 6D–60777, new camshafts metal stamped "V7L" are used intermittenly in the 4–53 and 6V–53 engines. These are low–velocity low–lift camshafts.

On 4–53 and 6V–53 engines the present low–lift camshaft must be used in conjunction with the new exhaust valve springs. Failure to change the exhaust valve springs could result in broken springs and engine failure. Refer to Section 1.2.2.

The low–lift camshaft which provides a maximum valve cam lobe lift of .276" is stamped "V7L" on both ends.

To provide proper camshaft end thrust, a new front camshaft pulley spacer is being used and the oil slinger has been eliminated, effective with engine serial numbers 3D–158108, 4D–164682 and 6D–180763. Engines built prior to 1968 were built with an oil slot broached in the camshaft end bearing. With pressure oil from this slot flowing directly on the upper front cover oil seal, the seal required the protection of an oil slinger. Even though the slot was eliminated in 1968 the use of the slinger was continued. With the elimination of the oil slinger, a new .025" longer spacer is used to make up for the removal of the slinger. Therefore, when removing the oil slinger(s) from an engine built prior to the above serial numbers, it will be necessary to replace the shorter spacer(s) with the new .025" longer spacer. Removal of the oil slinger on former engines is not mandatory. The former short spacer and slinger are for engines built prior to 1968 (engine serial numbers 2D–23442, 3D–44069, 4D–48900 and 6D–41029).

The new spacer is identified with a black oxide finish, the same part number also incorporates an optional material (powered metal) which is identified with an indent in the top surface below the chamfer.

A method of identifying a camshaft with the cylinder head still installed is as follows:

1. Put a dial indicator on the rocker arm clevis.
2. Bar the engine over 360° and the indicator will give a reading directly relative to the maximum amount of lift on the high point of the camshaft exhaust lobe.
   a. The 4–53 low–lift camshafts have a .276 maximum lift.
   b. The 4–53 high–lift camshafts have a .327 maximum lift.
3. The above can be accomplished with the cylinder head removed by placing the dial indicator directly on the exhaust valve lobe of the camshaft. A reading of the maximum camshaft lift can be taken at the high point of the lobe.

• New *camshafts, balance weights, and accessory drive pulleys* are used in turbocharged industrial engines equipped with crosshead pistons and bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545. The camshafts feature a revised cam lobe surface finish. To conform with the increased weight of the crosshead pistons, new rear balance weights and front cam and balance shaft pulleys are also required. The new weights and pulleys assist in maintaining an acceptable level of engine vibration.

> **NOTICE:** Do not mix trunk style and crosshead style piston assemblies in the same engine. Do not mix former and new balance weights in the same engine or use a former camshaft with a new camshaft in the same 6V–53 engine. Failure to observe these precautions can result in serious engine damage.

Lubrication

Lubrication is supplied under pressure to the camshaft and balance shaft end bearings via oil passages branching off from the main oil gallery direct to the camshaft end bearings.

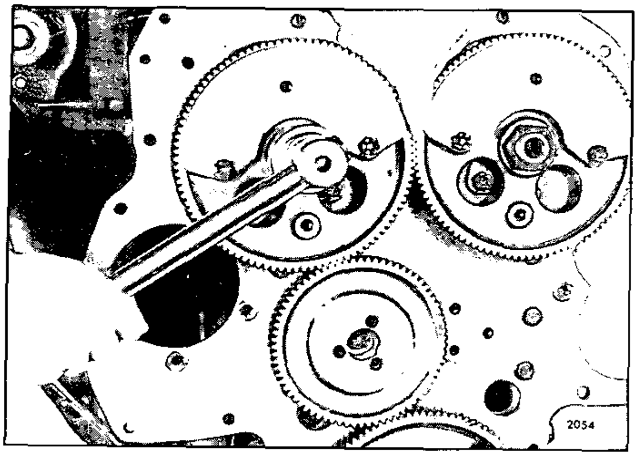


Fig. 1 – Removing or Installing Nut on Camshaft or Balance Shaft

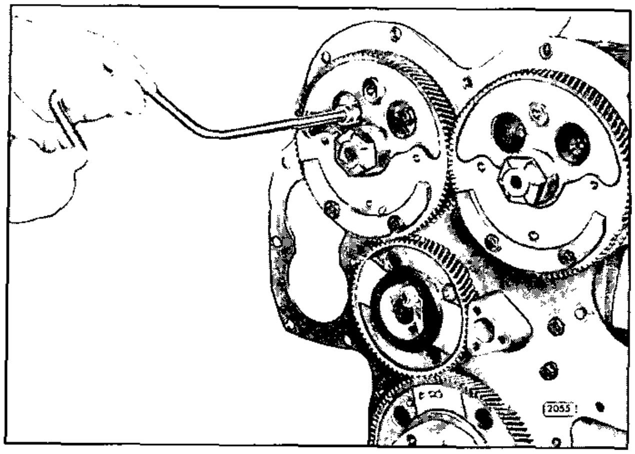


Fig. 2 – Removing or Installing Thrust Washer Retaining Bolts

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. On the current camshafts, the intermediate journal oil grooves were eliminated and a chamfer added to the intermediate journal oil holes. When replacing a former camshaft with a current camshaft, always use new bearings.

All of the camshaft and balance shaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the bearings, thrust washers or the gears need replacing, remove the shafts from the engine as follows:

Refer to *Shop Notes* in Section 1.0 to install a cup plug in the front end of the camshaft.

1. Drain the engine cooling system.
2. Remove all accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand (See Section 1.1).
3. Mount the engine on an overhaul stand. *Be sure the engine is securely mounted on the stand before releasing the lifting sling.*
4. Remove the cylinder head(s). Refer to Section 1.2.
5. Remove the flywheel and the flywheel housing as outlined in Sections 1.4 and 1.5.
6. Remove the bolts which secure the gear nut retainer plates (if used) to the gears, then remove the retainer plates.
7. Wedge a clean rag between the gears and remove the nuts from each end of both shafts with a socket wrench (Fig. 1).
8. Remove the balance pulleys from the front end of the shafts as outlined in Section 1.7.
9. Remove the upper engine front cover (Section 1.7.8).
10. Remove the oil slinger from the front end of both shafts.
11. Remove the two retaining bolts that secure the camshaft or balance shaft thrust washer to the cylinder block by inserting a socket wrench through a hole in the web of the gear (Fig. 2).
12. Withdraw the shaft, thrust washer and gear as an assembly from the rear end of the cylinder block.

Remove Camshaft (Flywheel Housing and Transmission in Place)

A camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission, if there is space enough to slide the shaft out through the front of the engine.

1. Drain the cooling system.
2. Remove the accessories and assemblies with their attaching parts that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the upper engine front cover (if used).
3. Remove the cylinder head.
4. Remove the gear nut retainer plates (if used).

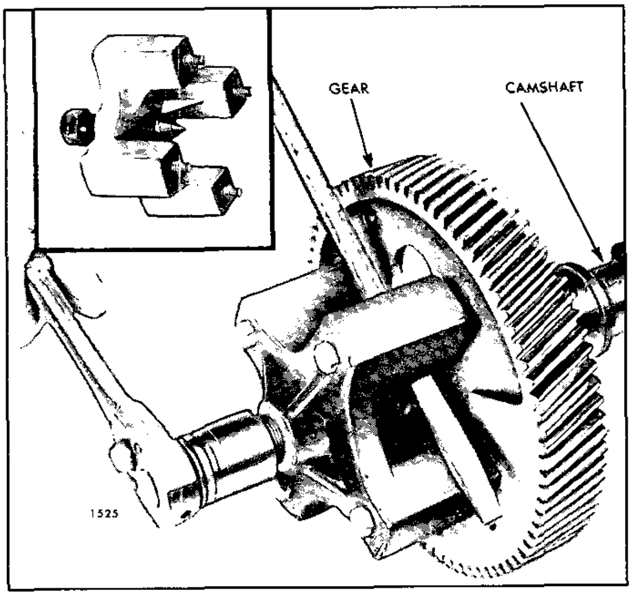


Fig. 3 – Removing Camshaft Gear with Tool J 1902–01

5. Wedge a clean rag between the gears and remove the gear retaining nut from each end of the camshaft (Fig. 1).

6. Remove the camshaft front balance pulley.

7. Remove the upper engine front cover (if used).

8. Remove the woodruff key from the camshaft and then remove the oil slinger.

9. Install the camshaft gear puller J 1902–01, four spacers J 6202–2 and camshaft gear puller adaptor plate J 6202–1 on the camshaft gear (Fig. 3).

10. Turn the center screw of the puller clockwise to disengage the camshaft gear. Do not remove the puller or the adaptor plate until the camshaft is reinstalled. The adaptor plate, secured to both the flywheel housing and the camshaft gear will hold the gear securely in place and in alignment which will aid in the reinstallation of the camshaft.

11. Pull the camshaft from the cylinder block.

Disassemble Camshaft or Balance Shaft

1. Remove the gear from the shaft. Refer to Section 1.7.3.

2. Remove the end plugs from the camshaft, to facilitate the removal of any foreign material lodged behind the plugs, as follows:

   a. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.

   b. Make an indentation in the center of the camshaft end plug with a 31/64″ drill (carboloy tip).

   c. Punch a hole as deeply as possible with a center punch to aid in breaking through the hardened surface of the plug.

   d. Then, drill a hole straight through the center of the plug with a 1/4″ drill (carboloy tip).

   e. Use the 1/4″ drilled hole as a guide and redrill the plug with a 5/16″ drill (carboloy tip).

   f. Tap the drilled hole with a 3/8″–16 tap.

   g. Thread a 3/8″–16 adaptor J 6471–2 into the plug. Then, attach a slide hammer J 2619–5 to the adaptor and remove the plug by striking the weight against the handle.

   h. Insert a length of 3/8″ steel rod in the camshaft oil gallery and drive the remaining plug out.

If a steel rod is not available, remove the remaining plug as outlined in Steps "a" through "g".

Inspection

Soak the camshaft in clean fuel oil. Then, run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the oil gallery and the oil holes with compressed air. Clean the gears, camshaft bearings and related parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam rollers as outlined in Section 1.2.1.

If there is a doubt as to the acceptability of the camshaft for further service determine the extent of cam lobe wear as follows:

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gages (.0015″–.0100″) and a piece of square hard material 1/8″ x 3/8″ x 1″ measure the flat on the injector rise side of the cam lobes (Fig. 4).

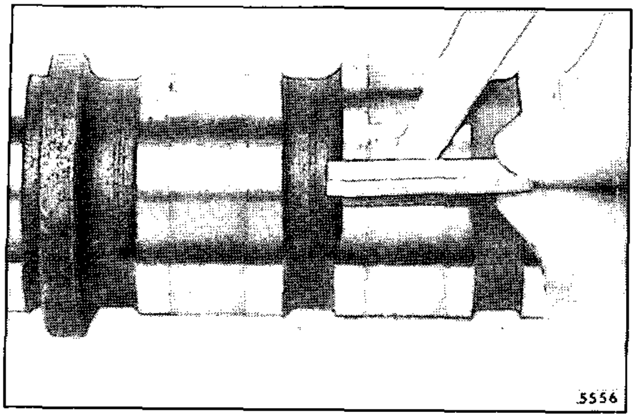


Fig. 4 – Checking Cam Lobe Wear

2. If the flats measure less that .003" in depth and there are no other defects the camshaft is satisfactory for service.

3. A slightly worn lobe still within acceptable limits, may be stoned and smoothed over with a fine crocus cloth.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Runout should not exceed .002".

Examine both faces of the thrust washers. If either face is scored or if the thrust washers are worn excessively, replace the washers. New thrust washers are .208" to .210" thick.

Also, examine the surfaces which the thrust washers contact; if these surfaces are scratched but not severely scored, smooth them down with an oil stone. If the score marks are too deep to be removed, or if parts are badly worn, use new parts. If a new camshaft is to be installed, thoroughly clean it to remove the rust preventive and blow out the oil passages with compressed air.

The clearance between new shafts and new bearings is .0035" to .007", or a maximum of .008" with worn parts. Excessive clearance between the shafts and the bearings will cause low oil pressure and excessive backlash between the gears.

Bearings are available in .010" and .020" undersize for use with worn or reground shafts.

Oversize camshaft and balance shaft bearings are available in sets, .010" oversize on the outside diameter, to permit reuse of a cylinder block having one or more scored block bearing bores. To use the oversize bearings, the camshaft and balance shaft block bores must be carefully line-bored (machined) to the dimensions shown in Table 1.

CAMSHAFT AND BALANCE SHAFT CYLINDER
BLOCK BORE MACHINING CHART

(Oversize Camshaft Bearings)

Engine	Bearing Location	Dimension	
		Minimum	Maximum
2,3,4,6V & 8V	End	2.385"	2.386"
2,3,4,6V & 8V	Intermediate*	2.375"	2.376"
4 & 8V	Center	2.365"	2.366"

*Center Bearing 2-53 Engine Only

TABLE 1

Remove Bearings

The end bearings must be removed prior to removing the intermediate bearings.

NOTICE: When removing the bearings be sure to note the position of the bearings in the bore with respect to the notch in the bearings. Replacement bearings must be installed in the same position.

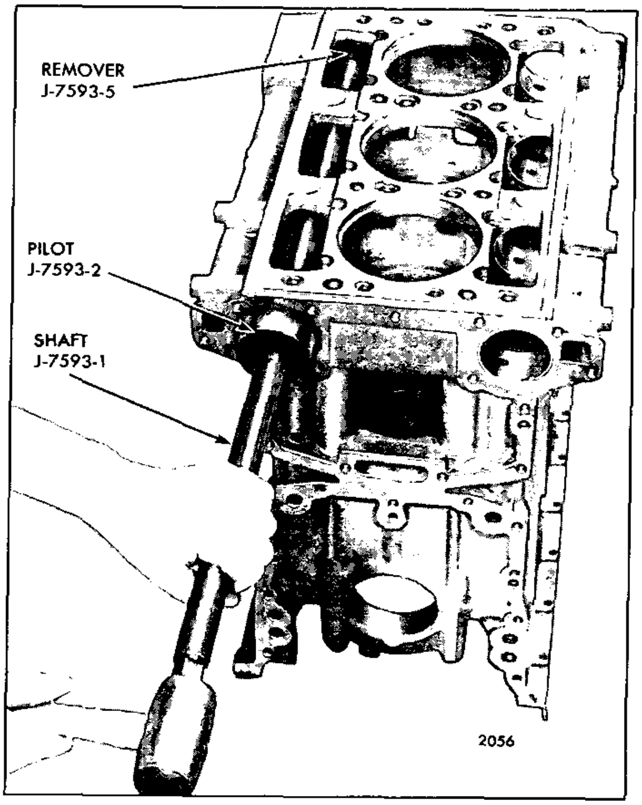


Fig. 5 – Removing End Bearing with Tools J 7593-1, J 7593-2 and J 7593-5

1. Remove all accessories and assemblies with their attaching parts as is necessary so that tool set J 7593–03 may be used as shown in Fig. 5 and in A of Fig. 6.

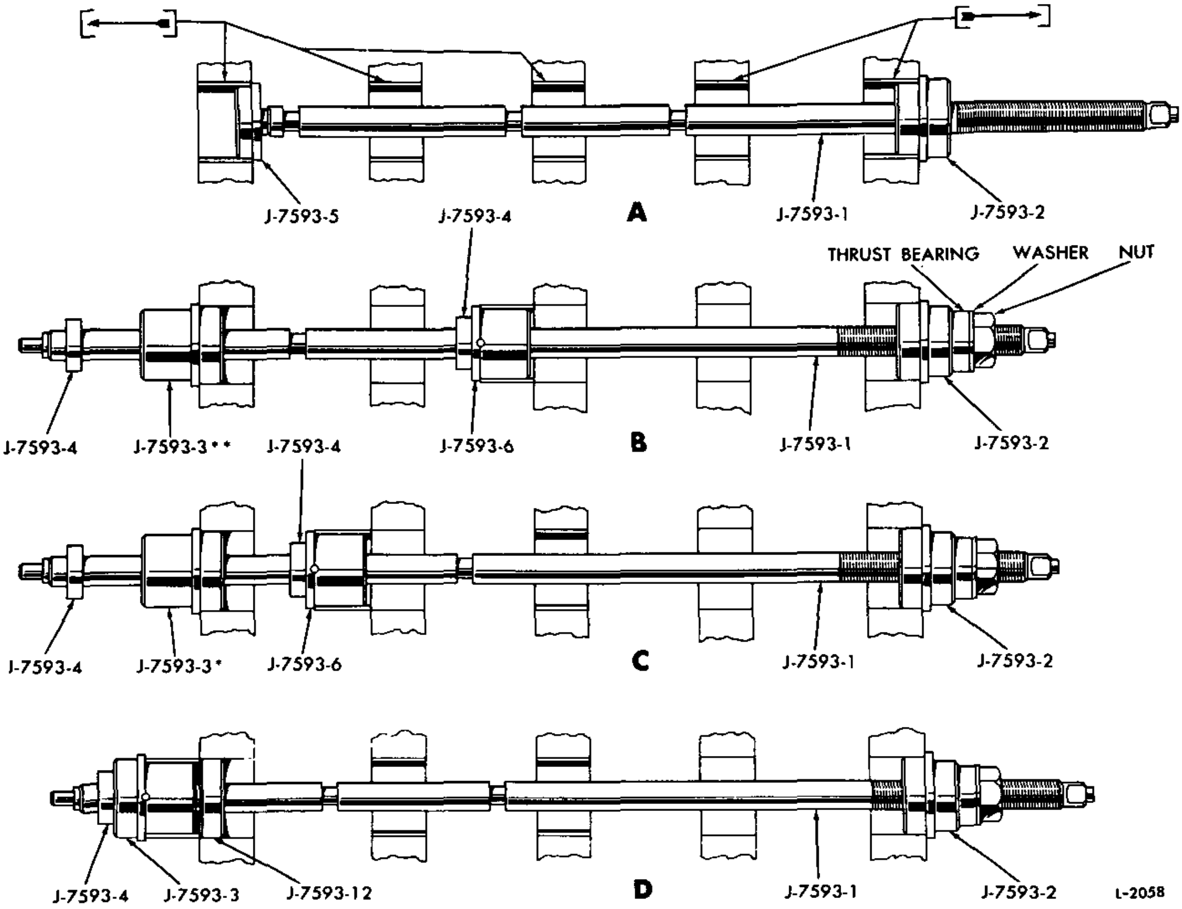
   Tool set J 7593–03, designed for use with standard size bearings, may be used to remove and install .010" undersize and .020" undersize bearings by reducing the pilot diameter of the pilot J 7593–2, installer J 7593–3, remover J 7593–5, installer J 7593–6 and installer J 7593–15.

   The pilot diameter of these tools should be reduced by .020". This reduction in tool diameter does not materially effect usage on standard size bearings. If the tools are used frequently, however, it may be advisable to purchase additional standard pieces. Reduced diameter tools have not been released.

2. Insert the small diameter end of the pilot J 7593–2 into the end bearing.

3. Then, with the unthreaded end of the shaft J 7593–1 started through the pilot, push the shaft through the block bore until the end of the shaft snaps into the remover J 7593–5.

4. Now drive the end bearing out of the cylinder block. The nearest intermediate and/or center bearings can be removed now in the same manner. The large diameter end of pilot J 7593–2 will fit into the camshaft bore and is used when removing the other end bearing and any remaining bearings.



*NOTE: Use J-7593-15 when installing the right front intermediate or left rear intermediate bearing in 6V cylinder block.

**NOTE: Use J-7593-15 in place of J-7593-3 as shown in Fig. 8 to install center bearing in 8V cylinder block.

Fig. 6 – Removing and Replacing Camshaft or Balance Shaft Bearings with Tool Set J 7593–03

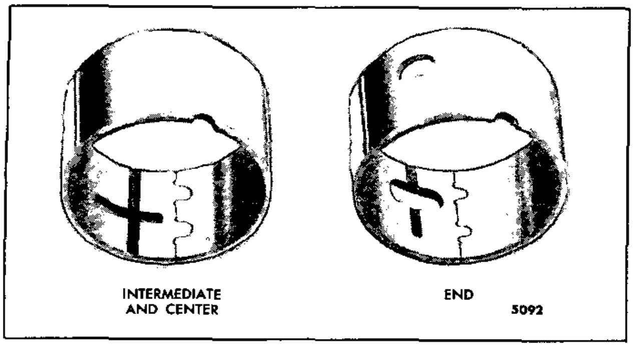


Fig. 7 – Camshaft and Balance Shaft Bearing Identification

Install Intermediate and/or Center Camshaft Bearings

Camshaft center and intermediate bearings must be installed prior to installing the camshaft end bearings. On the 4–53 and 8V engine, the center, rear intermediate and rear bearings are installed in that order by pressing the bearings from the rear to the front of the block. The front intermediate and front bearings are installed by pressing the bearings from the front to the rear of the block. Bearings are similarly installed in the 3–53 and 6V engine except that there is no center bearing. Current bearings incorporate lubrication grooves on the inner bearing surface (Fig. 7).

To properly install the camshaft and balance shaft bearings, refer to Fig. 8 for location of the notch in the bearing in relation to the camshaft or balance shaft bore centerline in the cylinder block.

Also, to facilitate assembly, the camshaft and balance shaft bearings are color coded on the side and/or end (Table 2).

1. Insert pilot J 7593–2 in the bore of the block (Fig. 9). Use the small end of the pilot if an end bearing has been installed. Refer to B and C of Fig. 6.

2. Insert the new intermediate or center bearing into the camshaft bore and position it correctly. Install the center bearing first.

3. Then, with the unthreaded end of shaft J 7593–1 started through the pilot, push the shaft through the entire length of the block bore.

4. Slide installer J 7593–6 on the shaft until the locating pin registers with the notch in the bearing. Then, slide installer J 7593–3 or J 7593–15 on the shaft with the large diameter inserted into the end of the block bore. Refer to C and NOTE of Fig. 6.

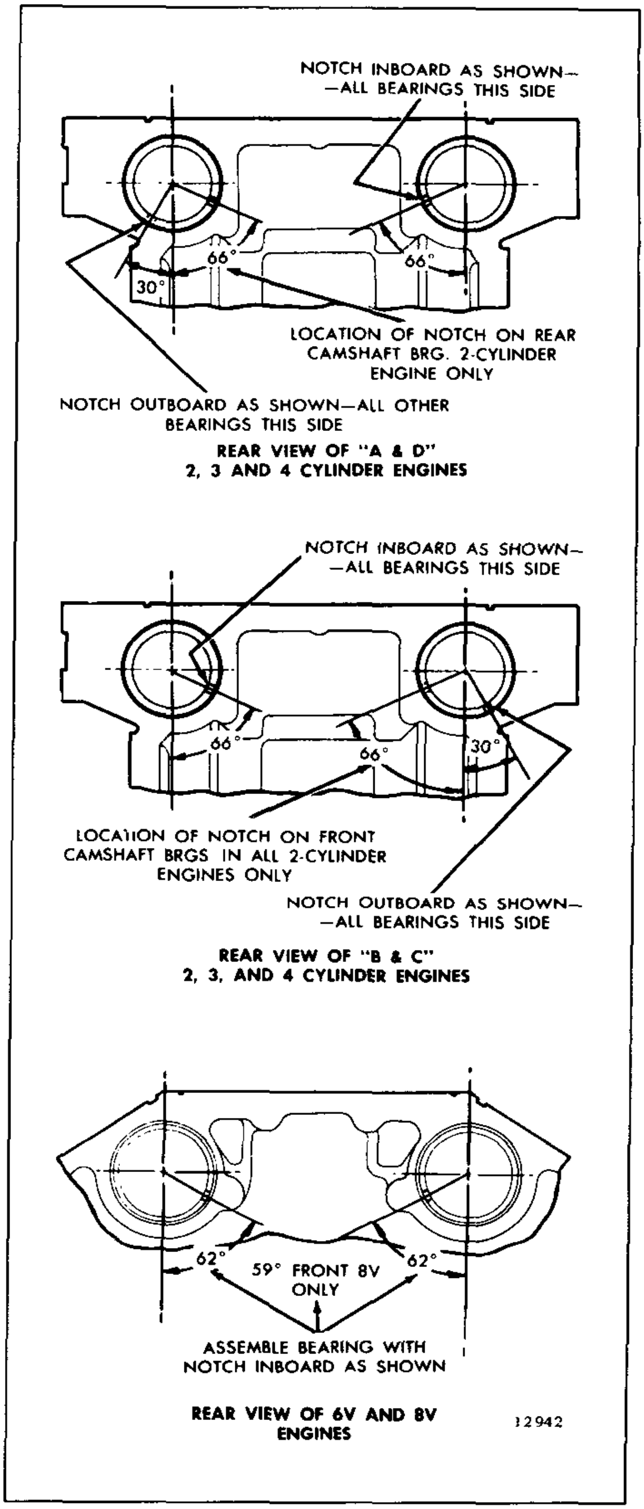


Fig. 8 – Location of Notch in Relation to Shaft Bore Centerline

5. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the puller. The short spacer J 7593–11, shown in Fig. 9, is used on the 3–53 and 6V blocks.

6. Align the shaft in such a way that a "C" washer, J 7593–4, can be inserted in a groove in the shaft adjacent to installer J 7593–6.

7. Place a "C" washer in the groove near the end of the shaft and, using a suitable wrench on the hex nut, draw the bearing into place until the "C" washer butts up against installer J 7593–3 and prevents the shaft from further movement.

Install End Bearings

Refer to the camshaft and balance shaft color code chart and the cylinder block bore machining dimension chart when installing the end bearings.

1. Insert pilot J 7593–2 in the bore of the block as shown in "D" of Fig. 9. Use the small diameter of the pilot if a bearing has been installed.

2. Insert support J 7593–12 in the bore in the opposite end of the block; then, with the unthreaded end of the shaft started through pilot J 7593–2, push the shaft through the block and support J 7593–12.

3. Place a new end bearing on installer J 7593–3 and align the notch in the bearings with the pin on the installer. Then, slide the installer and the bearing on the shaft. Position the bearing correctly with the groove in the camshaft bore.

4. Place "C" washer J 7593–4 in the end notch in the shaft; pull the shaft back until the washer butts against the installer.

5. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the shaft as shown in "D" of Fig. 6 and, using a suitable wrench on the hex nut, draw the bearing into place until the shoulder on the installer prevents the shaft from further movement. The bearing is now installed in its correct position.

Install the remaining end bearings in the same manner.

Use of tool set J 7593–03 assures that the bearings are properly spaced in relation to the end of the block. The center bearing (notch end) for a 4–53 and 8V cylinder block is 10.94″ from the rear face of the block. The intermediate bearings for the 3–53 and 4–53 block are 5.54″ from the rear and front face of the block. The right rear and left front intermediate bearings for the 6V and 8V cylinder block are 5.54″ from the rear and front face of the block; and the right front and left rear intermediate bearings are 6.66″ from the front and rear face of the block.

CAMSHAFT AND BALANCE SHAFT
BEARING COLOR CODE CHART

Bearing Position	Color Code		Outside Diameter	Inside Diameter
	Current	Former		
End	Brown	Black	Standard	Standard, .010″ & .020″ U.S.
	Brown	Yellow	.010″ Oversize	Standard (only)
Inter-mediate	Orange	Red	Standard	Standard, .010″ & .020″ U.S.
	Orange	Blue	.010″ Oversize	Standard (only)
Center (4-53-8V)	White	Green	Standard	Standard, .010″ & .020″ U.S.
	White	Red	.010″ Oversize	Standard*

*The former red center bearing of the standard set is also used as the intermediate bearing of the oversize (O.D.) set.

TABLE 2

Assemble and Install Camshaft and Balance Shaft

Refer to Fig. 10 and assemble the camshaft and balance shaft.

1. Coat the sides of the camshaft plugs with a light coating of Permatex Hi–Tack® or equivalent.

2. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940″ to 2.060″ (Fig. 11).

3. Install the gears and thrust washers on their respective shafts as outlined in Section 1.7.3.

4. Lubricate the bearings and shafts with engine oil and slide the shaft assemblies into the cylinder block being careful not to damage the bearings or the cams and journals. Make sure that the appropriate timing marks on the gears are aligned. Refer to *Gear Train and Engine Timing* in Section 1.7.1.

5. Slide an oil slinger on the front end of both shafts.

6. Install the upper engine front cover, if used, (Section 1.7.8).

7. Secure the thrust washers in place (Fig. 2) and tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

8. Install the front balance weights (Section 1.7).

9. Attach the gear nut retainer plates (if used) to the gears with bolts and lock washers and tighten the bolts to 35–39 lb–ft (47–53 N·m) torque.

10. Check the clearance between the thrust washer and the gear on both shafts. The clearance should be .005″ to .015″, or a maximum of .019″ with used parts.

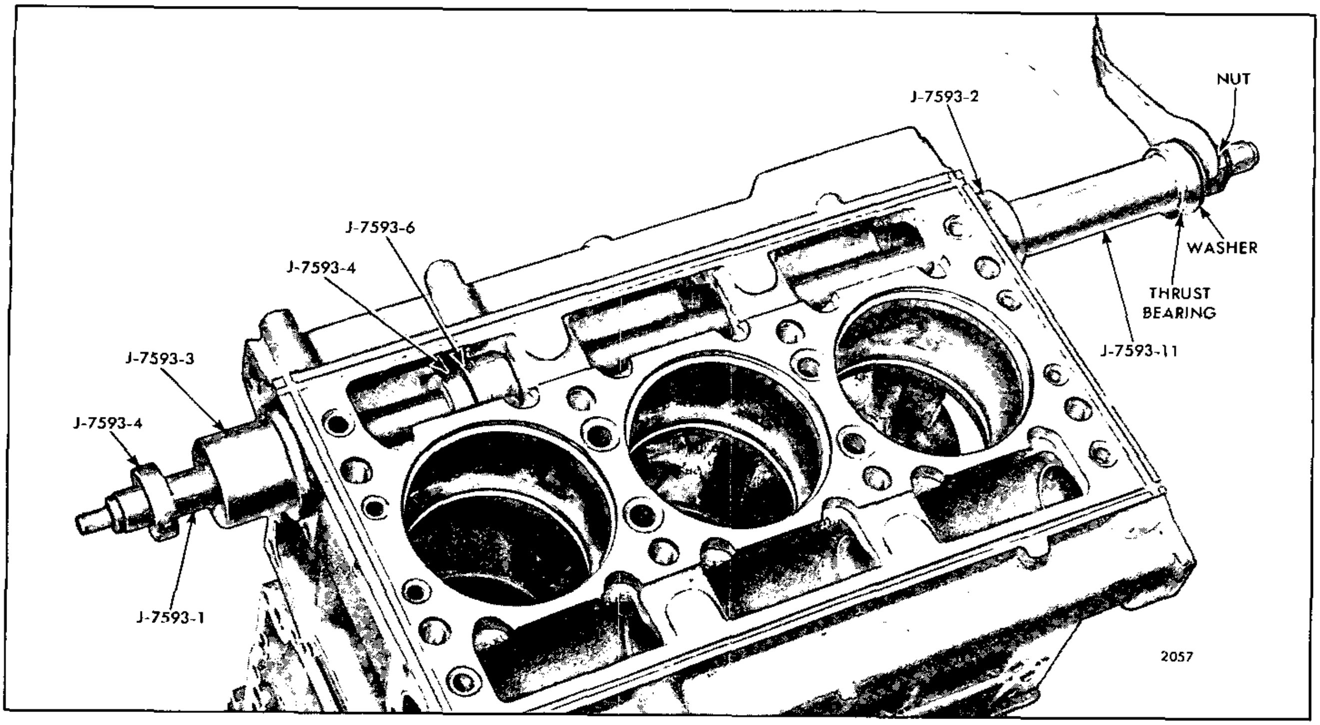


Fig. 9 – Installing Intermediate Camshaft Bearing Using Tool Set J 7593–03

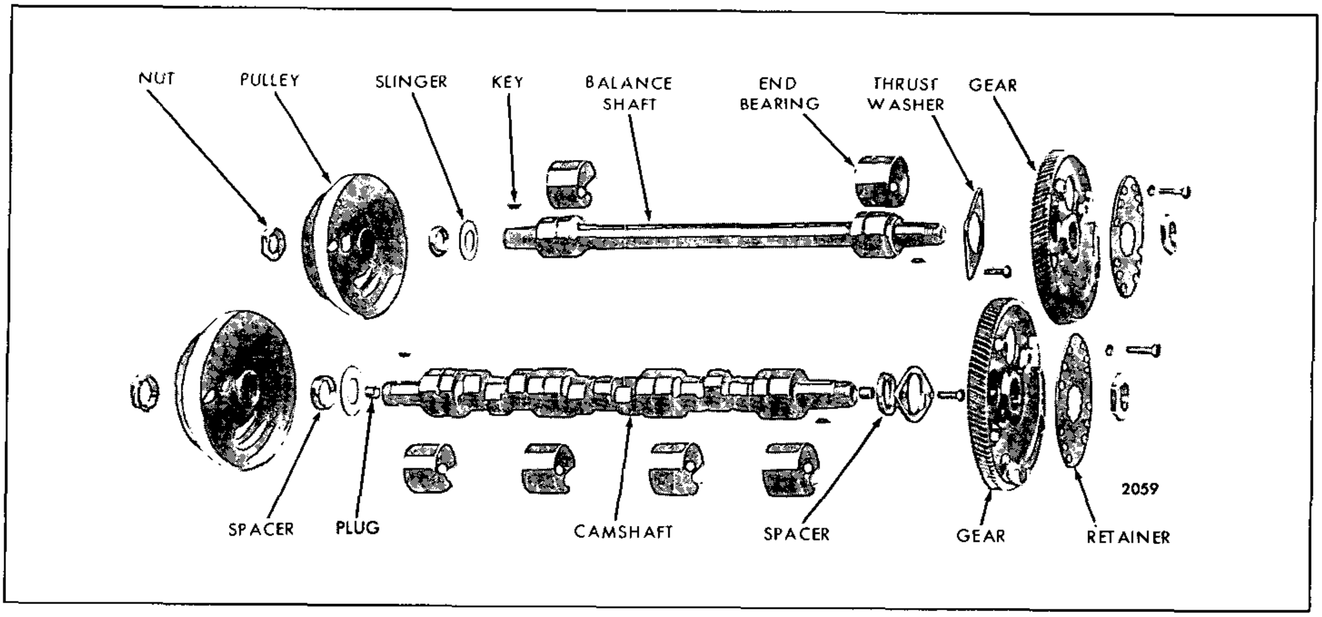


Fig. 10 – Camshaft and Balance Shaft Details and Relative Location of Parts

11. Check the backlash between the mating gears. The backlash should be .0005" to .005" and should not exceed .007" between used gears.

12. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective sections of this manual.

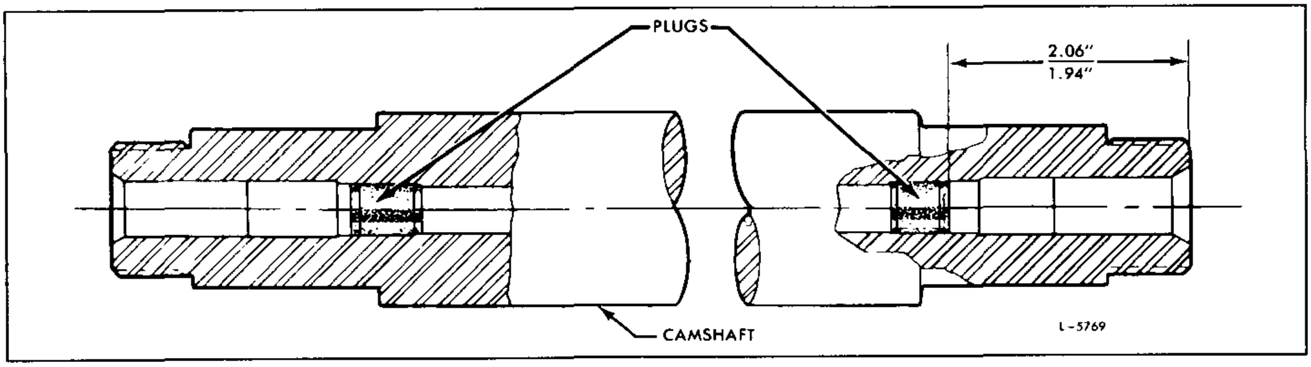


Fig. 11 – Camshaft Plug Installation

Install Camshaft (Flywheel Housing and Transmission in Place)

1. Place the rear camshaft spacer over the end of the camshaft and install the wooruff key in the gear end of the camshaft. Insert this end into position from the front of the engine. Push the shaft in until it slides into the end bearing.

2. Align the key in the shaft with the keyway in the camshaft gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

3. Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.

4. Install the oil slinger on the front end of the camshaft.

5. Install the upper front cover, if used, and slide the spacer over the end of the camshaft and into the oil seal in the cover.

6. Install the camshaft front balance pulley. Finger tighten the pulley retaining nut.

7. With the clean rag wedged between the gears to prevent their rotation, tighten the nut on each end of the camshaft to 300–325 lb–ft (407–441 N·m) torque.

8. Install the gear nut retainers with bolts and lockwashers. Tighten the bolts to 35–39 lb–ft (47–53 N·m) torque.

9. Install the accessories and assemblies that were removed and refill the cooling system.

CAMSHAFT AND BALANCE SHAFT GEARS

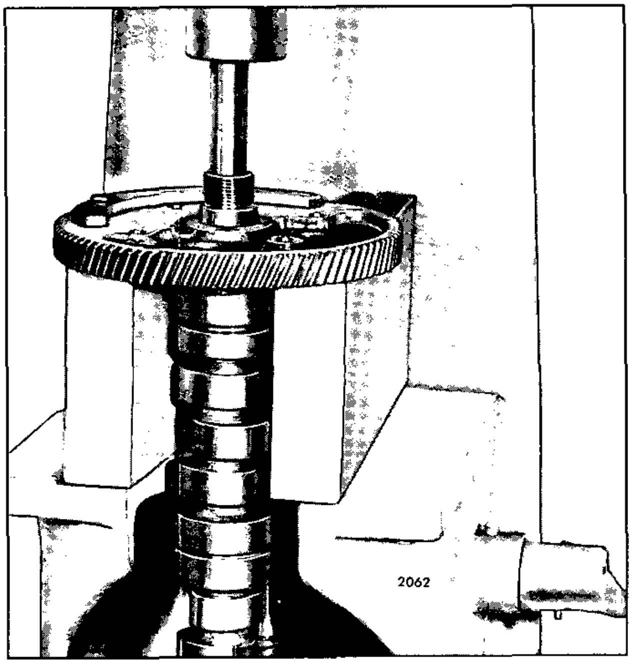


Fig. 1 – Removing Camshaft Gear

The camshaft and balance shaft gears on an In–line engine, and the two camshaft gears on a V–type engine, are located at the flywheel end of the engine and mesh with each other and run at the same speed as the crankshaft.

Since the camshaft and balance shaft gears on In–line engines and the two camshaft gears on V–type engines must be in time with each other, timing marks are stamped on the rim of each gear. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler and crankshaft gears (refer to Section 1.7.1 for gear train timing and identification of the new quiet gears and former gears).

Each gear is keyed to its respective shaft and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut on some engines. The retainer is attached to the gear by bolts threaded into tapped holes in the gear.

On the two, three and four cylinder In–line engines, external weights are attached to the rear face of each gear. Different size weights are used on the two, three and four cylinder engines. The weights are important in maintaining perfect engine balance. Additional weights are not required on the 6V engine camshaft gears or on the 8V engines effective with 8D–127.

When new service gears are used on an In–line engine, or an early 8V engine, the external weights on the old gears must be transferred to the new gears. If the weights are transferred to new gears, tighten the bolts to 45–50 lb–ft (61–68 N·m) torque.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3–53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D–193516 and 6D–229616.

When cross–head pistons are to be installed in a turbocharged Series 53 engine built prior to serial numbers 3D–193526, 4D–209292, 6D–229545 and an in–frame overhaul is desired, new bolt–on balance weights must be used.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and the balance shaft from the engine as outlined in Section 1.7.2.
2. Place the camshaft and gear assembly in an arbor press with the gear suitably supported (Fig. 1).
3. Place a wood block under the lower end of the camshaft so the threads will not be damaged when the shaft is pressed from the gear.
4. Place a short piece of 3/4" O.D. brass rod on the end of the camshaft and press the camshaft out of the camshaft gear.
5. Remove the thrust washer, Woodruff key and spacer from the camshaft.
6. Remove the gear from the balance shaft in a similar manner.

Inspection

Clean the gears with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Then, examine the gear teeth for evidence of scoring, pitting and wear. Replace the gears, if necessary.

Examine both faces of the camshaft and balance shaft thrust washer and, if either face is worn or scored, replace the washer. Also, examine the surface on the camshaft and balance shaft which the thrust washer contacts. If this surface is scratched, but not severely scored, smooth it up with a fine oil stone.

Install Camshaft and Balance Shaft Gears

1. Note the letters stamped on the end of the camshaft which signify the engine models in which a camshaft may be used. The letters on the timing gear end of the camshaft must correspond with the engine model of the particular engine being assembled. Refer to the front of this manual for engine model identification.

2. Place the rear camshaft spacer over the timing gear end of the camshaft and install the Woodruff key.

3. Lubricate the thrust washer with clean engine oil and place the thrust washer over the gear end of the camshaft and the spacer.

4. Start the camshaft gear over the end of the camshaft with the key in the shaft registering with the keyway in the gear.

5. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and press the gear tight against the spacer on the shaft (Fig. 2).

6. Measure the clearance between the camshaft thrust washer and the camshaft. This clearance should be .008″ to .015″ when new parts are used. With used parts, a maximum clearance of .021″ is allowable.

7. Install the gear retaining nut on the camshaft by hand. *Tighten the nut after the shaft is installed in the* cylinder block.

8. Install the gear on the balance shaft in a similar manner. No rear spacer is used with the balance shaft gear since the gear seats against a shoulder on the shaft.

9. Install the camshaft and balance shaft in the engine as outlined in Section 1.7.2.

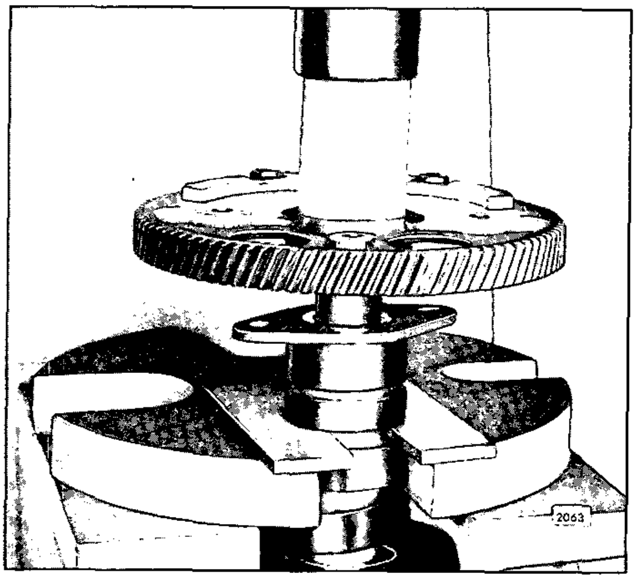


Fig. 2 – Installing Camshaft Gear

IDLER GEAR AND BEARING ASSEMBLY

IN–LINE AND 6V–53 ENGINES

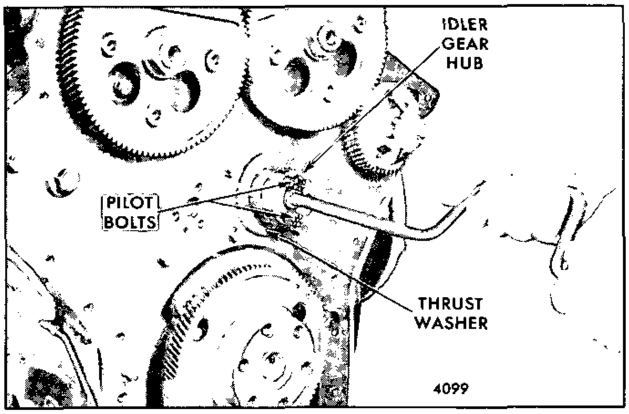


Fig. 1 – Installing Idler Gear Hub

The engine idler gear and bearing assembly, located at the flywheel end of the engine, meshes with the camshaft and crankshaft gears and rotates on a stationary hub. The hub is secured directly to the cylinder block by a bolt which passes through the hub and three bolts which pass through the flywheel housing, hub and end plate (Fig. 1).

Two timing marks (a triangle within a circle) are stamped on the idler gear diametrically opposite (180°) to one another.

The inside diameter of the idler gear bearing is 2.186" – 2.187" and the outside diameter of the idler gear hub is 2.1825" – 2.1835". Therefore, the clearance between the idler gear hub and the idler gear bearing is .0025" to .0045", with a maximum allowable wear limit of .007".

A thrust washer is provided on both sides of the idler gear and bearing assembly. The standard thickness of the idler gear and bearing assembly is 1.233" to 1.234" and the standard thickness of the two thrust washers is .236" to .240". Therefore, the clearance between the thrust washers and the idler gear is .006" to .013", with a maximum allowable wear limit of .017".

On an In–line engine, the idler gear is positioned on the left–hand side for a right–hand rotating engine and on the right–hand side for a left–hand rotating engine as viewed from the rear. On a 6V engine, the idler gear is positioned on the right–hand side for a right–hand rotating engine and on the left–hand side for a left–hand rotating engine, as viewed from the rear. Refer to *General Description.*

On early engines, an idler gear spacer (dummy hub) was used on the side opposite the idler gear. Currently, the flywheel housing has an integral cast hub and a .015" thick shim is used between the flywheel housing and the end plate.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3–53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D–193516 and 6D–229616.

Remove Idler Gear and Bearing Assembly (Flywheel Housing Removed)

1. Remove the idler gear outer thrust washer from the idler gear hub (Fig. 2).

2. Slide the idler gear straight back off of the idler gear hub.

3. Remove the bolt which secures the idler gear hub to the cylinder block. Then, remove the idler gear hub and the idler gear inner thrust washer as an assembly.

Inspection

Wash the idler gear and bearing assembly, hub and thrust washers thoroughly in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the gear teeth and bearing for scoring, pitting or wear. If the gear teeth are worn or the bearing is scored, pitted or worn excessively, replace the gear and bearing assembly or install a new bearing in the gear. Examine the outside diameter of the idler gear hub and thrust washers. If scored or worn excessively, replace them.

An idler gear bearing with two oil grooves has been incorporated in the idler gear and bearing assemblies beginning with engine serial numbers 2D–14301, 3D–6773, 4D–9458 and 6D–3334.

When a new bearing (bushing) is installed in the idler gear, it must not protrude beyond the gear face on either side and must sustain an axial load of 2,000 pounds minimum without pushing out of the gear.

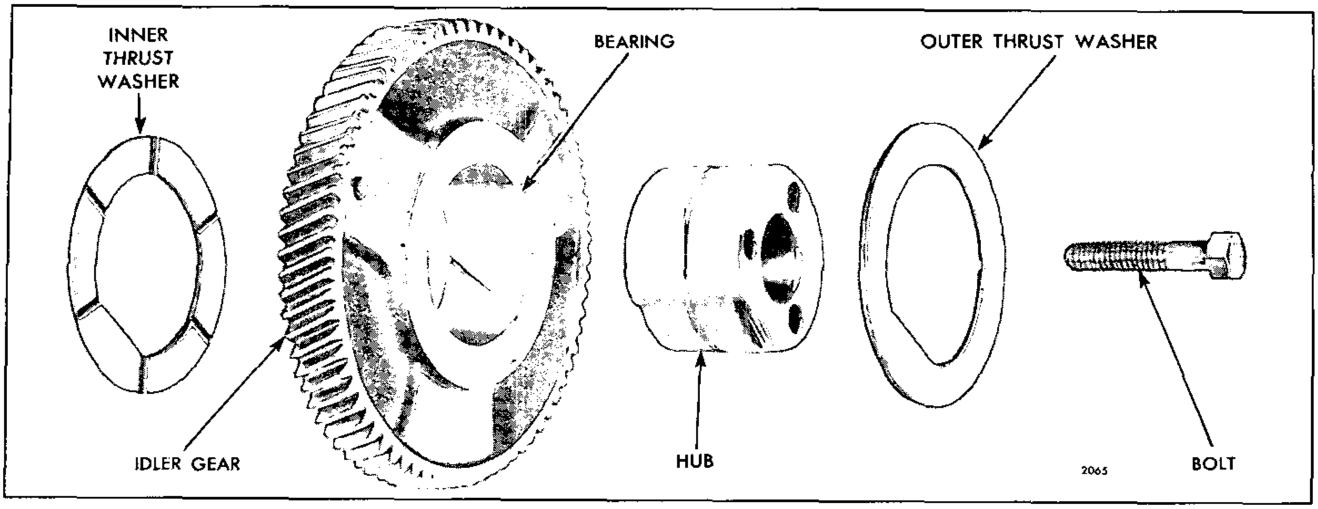


Fig. 2 – Idler Gear Details and Relative Location of Parts

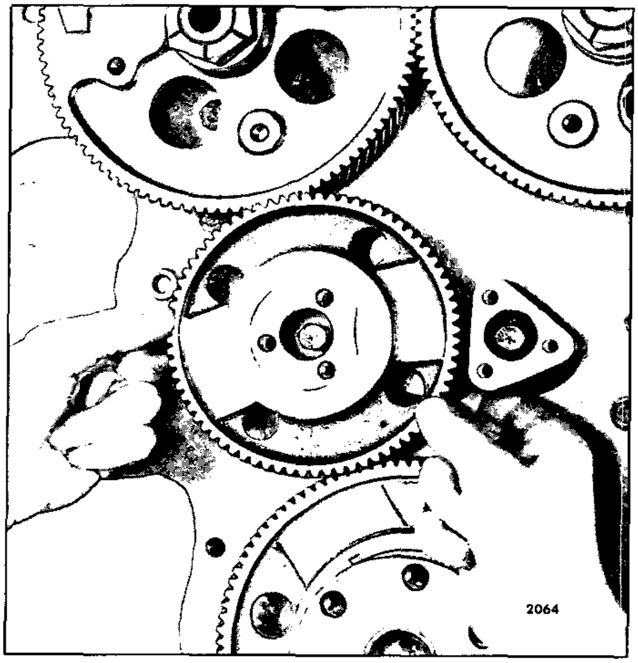


Fig. 3 – Installing Idler Gear

Install Idler Gear and Bearing Assembly

1. Place the inner thrust washer on the forward end of the idler gear hub with the flat in the inner diameter of the thrust washer over the flat on the end of the gear hub and with the oil grooves in the thrust washer facing the idler gear.

2. Place the small protruding end of the idler gear hub through the end plate and into the counterbore in the cylinder block.

3. Insert two 3/8"–16 bolts through the idler gear hub and thread them into the cylinder block (Fig. 1), to be sure the bolt holes will be in alignment when the flywheel housing is installed.

4. Insert the 3/8"–16 x 1–3/4" special bolt through the center of the idler gear hub and thread it into the cylinder block. Tighten the bolt to 40–45 lb-ft (54–61 N·m) torque. Then, remove the two 3/8"–16 bolts previously installed for alignment of the gear hub.

5. Lubricate the idler gear hub and idler gear bearings liberally with clean engine oil.

6. Position the crankshaft gear and the camshaft gear or balance shaft gear so that their timing marks will align with those on the idler gear. Refer to Figs. 1 and 2 and *to Table 1 in Section 1.7.1 for identification of the* new quiet gears and the former gears.

7. With these timing marks in alignment, install the idler gear (Fig. 2).

8. Apply a thin film of cup grease to the inner face (face with the oil grooves) of the outer idler gear thrust washer. Then, place the thrust washer over the end of the idler gear hub with the oil grooves in the side of the thrust washer facing the idler gear and the flat in the inner diameter of the thrust washer over the flat on the end of the idler gear hub.

9. Check the backlash between the mating gears. The backlash should be .0005" to .005" between new gears and should not exceed .007" between used gears.

8V-53 ENGINE

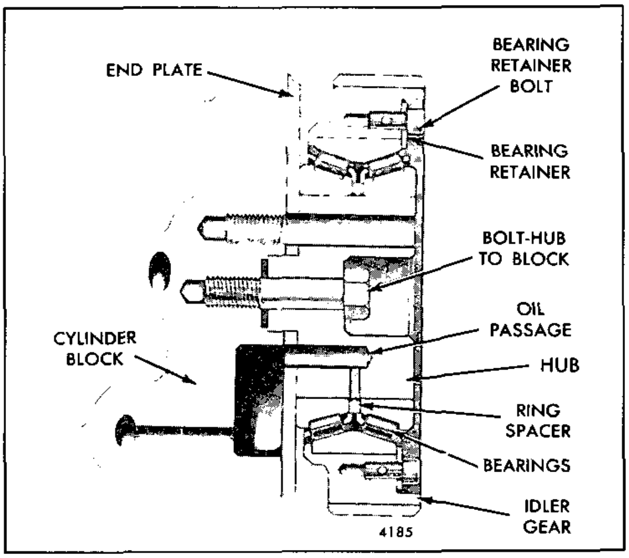


Fig. 4 – Idler Gear Mounting (Former Bearing)

Fig. 4 illustrates the mounting of the roller bearing type idler gear. When replacing any part of the gear assembly, a complete roller bearing type idler gear assembly must be used.

The idler gear is mounted on a double–row, tapered roller bearing which, in turn, is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate.

The current idler gear bearing consists of two cups, two cones and an outer and inner spacer ring. The former idler gear bearing consists of a cup, two cones and a spacer ring.

The inner races of the idler gear bearing are pressed on the gear hub and, therefore, do not rotate. A spacer separates the two bearing inner cones. The bearing cup(s) has a light press fit in the idler gear and is held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six bolts on the other side.

Two timing marks (a triangle within a circle) are stamped on the idler gear, diametrically opposite (180°) to one another.

A dummy hub cast into the flywheel housing is used on the side opposite the idler gear. A shim is used between the dummy hub and the rear end plate. The flywheel housing bears against the inner races of the idler gear bearing and also against the dummy hub. Three self–locking bolts are used to attach the flywheel housing at the idler gear and dummy hub locations.

Remove Idler Gear, Huband Bearing Assembly (Flywheel Housing Previously Removed)

Remove the hub to cylinder block bolt and withdraw the assembly from the cylinder block rear end plate.

Before removing the idler gear, check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure is applied by firmly grasping the rim of the gear with both hands and rocking the gear in relation to the bearing. The bearing must be replaced if the gear wobbles or shakes. If the gear assembly is satisfactory, it is only necessary to check the pre–load before reinstallation.

Disassemble Idler Gear, Hub and Bearing Assembly

While removing or installing an idler gear bearing, the bearing *must* be rotated to avoid the possibility of damaging the bearing by brinelling the bearing cones. Brinelling refers to the marking of the cones by applying a heavy load through the rollers of a non–rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the cones. These impressions may not be easily discerned during normal inspection. For example, a bearing may be brinelled if a load were applied to the inner cone of the bearing assembly in order to force the outer cone into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

Refer to Fig. 4 for the location and identification of parts and disassemble the bearing as follows:

1. Remove the six bolts which secure the bearing retainer to the idler gear.

   Component parts of the idler gear bearing are mated. Therefore, matchmark the parts during disassembly to ensure that they will be reassembled in their *original* positions.

2. Clean the idler gear and bearing assembly with fuel oil and dry it with compressed air.

3. Place the idler gear and bearing assembly in an arbor press with the bearing cone or inner race supported on steel blocks (Fig. 5). While rotating the gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacer.

4. Tap the bearing cups and spacer (current gear) or bearing cup (former gear) from the idler gear by using a brass drift alternately at four notches provided around the shoulder of the gear (Figs. 6 and 7).

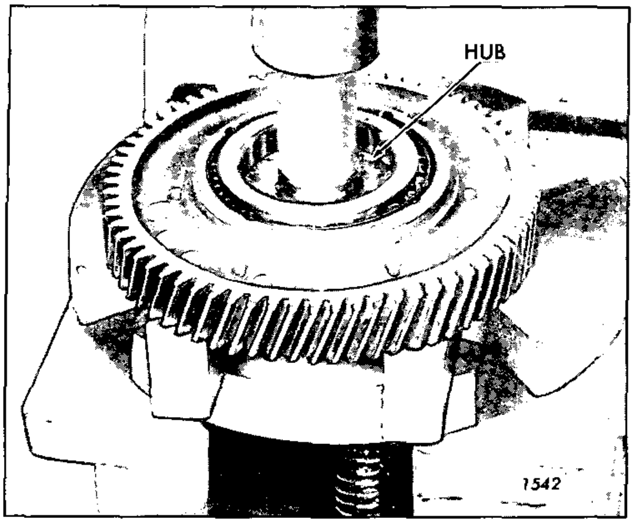


Fig. 5 – Pressing Hub Out of Bearing

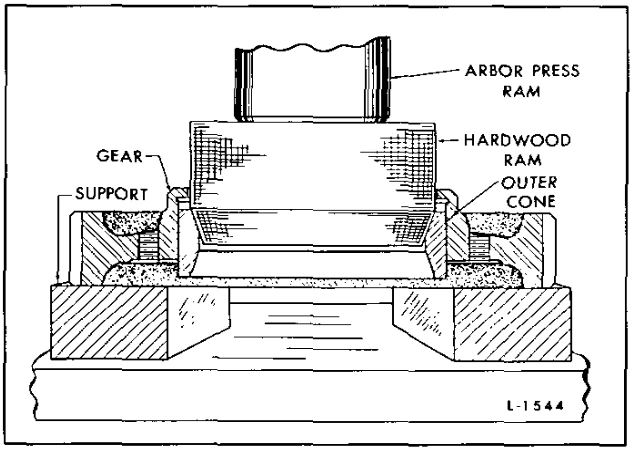


Fig. 6 – Hardwood Ram for Pressing Outer Bearing Race from Gear

Inspection

Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal *injury, wear adequate eye protection* and do not exceed 40 psi (276 kPa) air pressure.**

Check the idler gear hub to ensure that no chips or foreign material is deposited in the holes to cause interference with the flywheel housing attaching bolts.

Inspect the bearing carefully for wear, pitting, scoring or flat spots on the rollers or cones. Replace the bearing if it is defective.

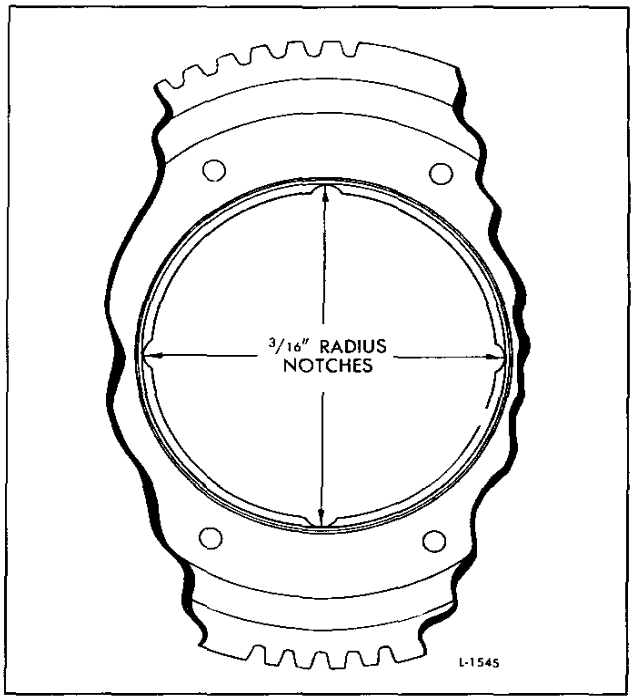


Fig. 7 – Location of Notches in Idler Gear

Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, replace the gear. Also, inspect the other gears in the gear train.

Assemble Idler Gear, Hub and Bearing

CURRENT BEARING

Refer to Fig. 8 and assemble the bearing components in their *original positions* (refer to identification marks made during disassembly) as outlined below:

The current idler gear bearing is a matched assembly. *Do not* mix the components with those of another gear.

1. Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then, press the bearing cup *against the shoulder of the gear.* Use a flat round steel plate (pre–load test plate) between the ram of the press and the bearing cup.
2. Lay the outer spacer ring on the face of the bearing cup.
3. Start the other bearing cup, numbered side down, squarely into the bore of the gear. Then, press the cup tight against the spacer ring. Use a flat round steel plate (pre–load test plate) between the ram of the press and the bearing cup.
4. Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face.

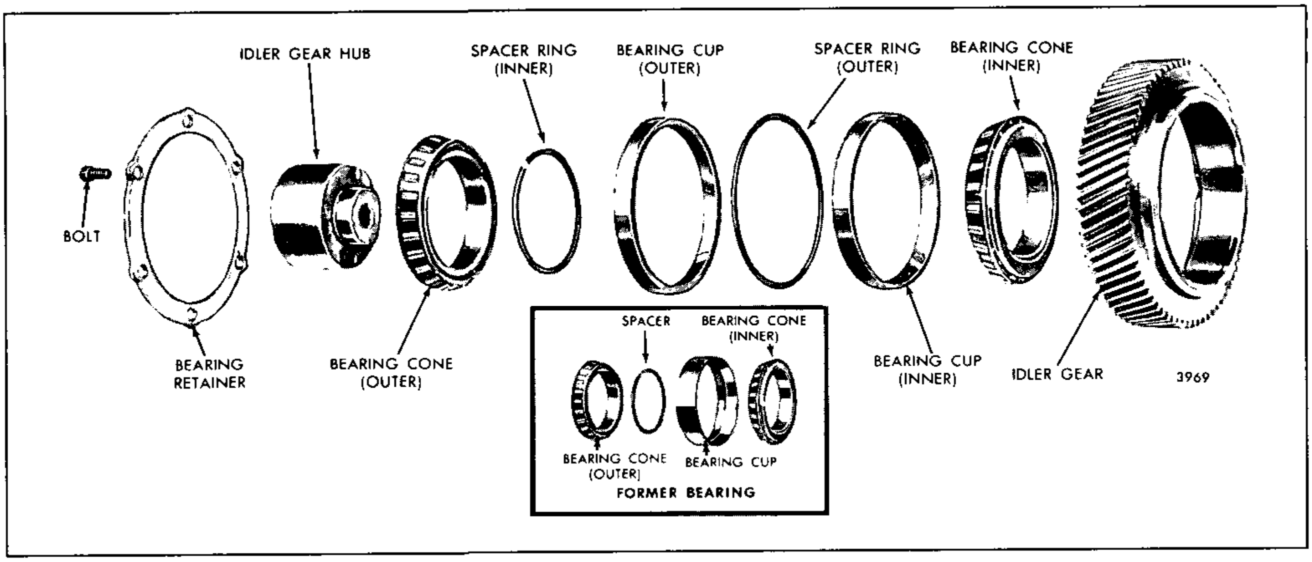


Fig. 8 – Idler Gear Details and Relative Location of Parts (Current Bearing)

Use the pre–load test plate (with the large center hole) between the ram of the press and the bearing.

5. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180° from the gap in the inner spacer ring.

6. Position the gear with both cups over the hub and the inner bearing cone.

7. Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation.

8. Before installing the gear and bearing assembly, check the pre–load.

FORMER BEARING

Assemble the bearing components in their *original* positions (refer to the identification marks made during disassembly) as outlined below.

1. Support the idler gear, shoulder side down, on an arbor press and start the outer bearing cone squarely into the bore of the gear. Then, press the bearing cone tight against the shoulder of the gear, using a steel plate between the ram of the press and the bearing cone.

2. Support one bearing cone, numbered side down, on the arbor press and lower the idler gear and bearing cup assembly down over the bearing cone.

3. Place the spacer ring on the face of the bearing cone.

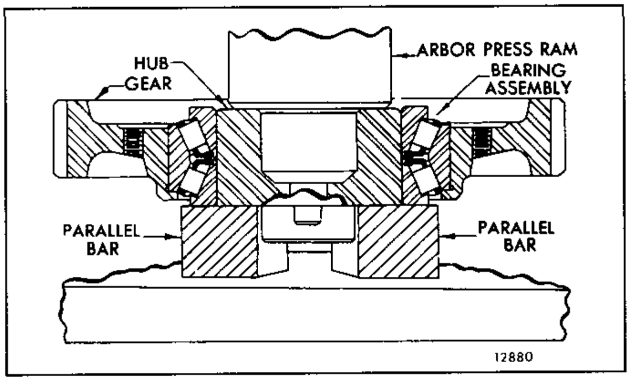


Fig. 9 – Pressing Hub into Bearing

4. Place the second bearing cone, numbered side up, in the idler gear and bearing cup assembly and against the spacer ring.

5. Then, position the idler gear hub over the bearing cones so that the oil hole in the hub is 180° from the gap in the spacer ring.

6. Press the hub into the idler gear bearing cones, while rotating the gear (to seat the rollers properly between the cones), until the face of the hub which will be adjacent to the cylinder block end plate is flush with the corresponding face of the bearing cone. The bearing cones should be supported so as not to load the bearing rollers during this operation (Fig. 9).

7. Prior to installing and securing the bearing retainer, check the pre–load of the bearing assembly as outlined below.

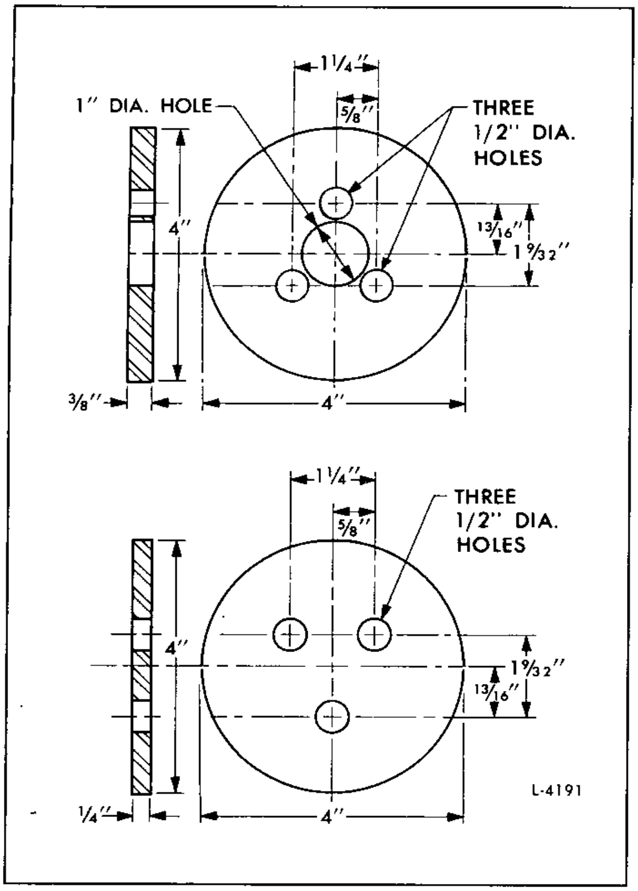


Fig. 10 – Plates for Bearing Test Fixture

Check Pre–Load of Bearing

The rollers of the bearing are loaded between the bearing cup and bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be more tightly held between the cones and the cup. In the idler gear bearings, a slight pre–load is applied, by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre–loading is measured, in terms of "pounds–pull", by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs, the pre–load should be measured as part of the operation.

The idler gear bearing should be clean and lubricated with light engine oil prior to the pre–load test. Idler gear assemblies which include new bearings should be "worked in" by grasping the gear firmly by hand and rotating the gear back and forth several times.

After the idler gear, hub and bearing are assembled together, the bearing should be checked to ascertain that the gear may be rotated on its bearing without exceeding the maximum torque specifications, nor be so loose as to permit the gear to be moved in relation to the hub by tilting, wobbling or shaking the gear.

If the mating crankshaft and camshaft gears are not already mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a round steel plate 4" in diameter (pre–load test plate) against the hub and cone as outlined below.

1. Mount the idler gear assembly on the engine.
2. Install the center bolt through the gear hub and thread it into the cylinder block. Tighten the bolt to 40–45 lb–ft (54–61 N·m) torque.
3. Place the steel plate (lower plate shown in Fig. 10) against the hub and bearing. Insert two 3/8"–16 bolts and one 5/16"–18 bolt through the plate and thread it into the cylinder block. Tighten the two 3/8"–16 bolts to 40–45 lb–ft (54–61 N·m) torque and the 5/16"–18 bolt to 19–23 lb–ft (26–31 N·m) torque.
4. Tie one end of a piece of lintless 1/8" cord around a 1/8" round piece of wood (or soft metal stock). Place the wood between the teeth of the gear, then wrap the cord around the periphery of the gear several times. Attach the other end of the cord to a spring scale, J 8129 (Fig. 11). Maintain a straight, steady pull on the scale, 90° to the axis of the hub, and note the pull, in pounds and ounces, required to start the gear rotating. Make several checks to obtain an average reading. If the pull is within 1–1/4 lb. minimum to 6 lbs. 12 ounces maximum and does not fluctuate more than 2 lbs. 11 ounces, the idler gear and bearing assembly are satisfactory for use.

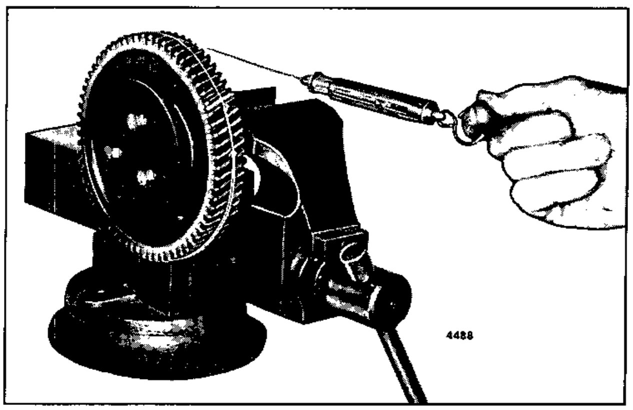


Fig. 11 – Checking Pre–Load of Idler Gear Bearing

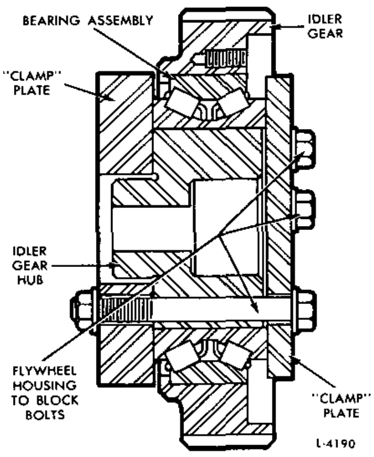


Fig. 12 – Fixture for Testing Bearing Pre–Load

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture which may be held in a vise can be made with two plates (Figs. 10 and 12). One of the plates is used to take the place of the flywheel housing and the other the cylinder block. *Engine–mounted* conditions are simulated by tightening the 3/8"–16 attaching bolts and nuts nuts to 40–45 lb–ft (54–61 N·m) torque.

Check the pre–load as follows:

1. Clamp the idler gear between the two plates (Fig. 12). Insert the bolts and tighten the three 3/8"–16 bolts and nuts to 40–45 lb–ft (54–61 N·m) torque.
2. Clamp the idler gear assembly and fixture in a vise (Fig. 10).
3. Attach the cord to the idler gear and spring scale and check the pre–load as outlined in Step 4 of the previous method.

If the scale reading is within the specified 1–1/4 to 6–3/4 lbs., but fluctuates more than the permissible 2 lbs. 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones not being concentric to each other, damaged cones or rollers, or dirt or foreign material within the bearings. The bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed.

A scale reading which exceeds the specified maximum indicates binding of the bearing rollers or rollers improperly installed. When the scale reading is less than the specified minimum, the bearing is more likely worn and the bearing should be replaced.

After the pre–load test is completed, remove the steel plates. Attach the bearing retainer to the idler gear with six self-locking bolts. Tighten the bolts to 12–15 lb–ft (16–20 N·m) torque.

Install Idler Gear, Hub and Bearing Assembly

1. Position the crankshaft gear and the camshaft gear so that the timing marks will align with those on the idler gear (refer to Section 1.7.1).
2. With these marks in alignment, start the idler gear into mesh with the crankshaft gear and the camshaft gear and simultaneously rotate the gear hub so that the oil hole in the rear end plate is in line with the oil hole in the hub and the three bolt holes are in line.
3. Roll the idler gear into position and gently tap the hub until it seats against the rear end plate.
4. After making sure that the hub is tight against the rear end plate, secure the idler gear assembly in place with the 3/8"–16 x 1–3/4" special bolt. Tighten the bolt to 40–45 lb–ft (54–61 N·m) torque.
5. Lubricate the idler gear and bearing liberally with clean engine oil.
6. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.

CRANKSHAFT TIMING GEAR

IN-LINE AND 6V-53 ENGINES

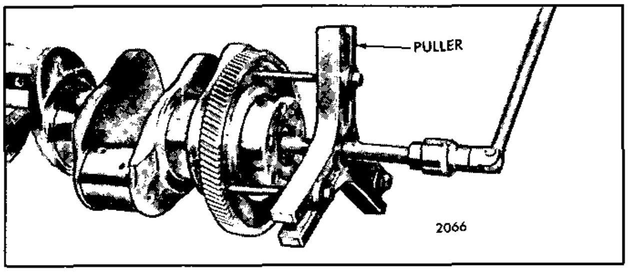


Fig. 1 – Removing Crankshaft Timing Gear with Puller J 4871

The crankshaft timing gear is keyed and pressed on the crankshaft and drives the camshaft gear (In-line or 6V-53 engines) or balance shaft gear (In-line engines) through an idler gear. A quiet gear train was introduced in 53 Series engines effective with engines 3D-170683, 4D-180939 and 6D-196535.

Since the camshaft must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to Section 1.7.1 for gear train timing and identification of the new quiet gears and the former gears).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The former crankshaft timing gear is a .001" to .003" press fit on the crankshaft. The current 111 toothed gear is a .0015" to .0035" press fit on the crankshaft. The crankshaft diameter at this point is 4.060" to 4.061". Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.
2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.
3. Attach bar type puller J 4871 to the crankshaft gear with three long bolts or hooks, flat washers and nuts through the holes in the gear (Fig. 1).
4. Turn the center screw of the puller to pull the crankshaft gear off of the crankshaft.

Inspection

Clean the gear with fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also, check the other gears in the gear train.

Install Crankshaft Timing Gear

Before the crankshaft timing gear is installed, measure the inside diameter of the gear and outside diameter of the butt end of the crankshaft to assure the correct press fit.

- The inside diameter of the current 111 tooth gear is 4.0575" to 4.0585". The former 97 tooth gear inside diameter is 4.0580" to 4.0590".
- The outside diameter of the butt end of the crankshaft is 4.060" to 4.061".

If either the crankshaft or gear are beyond specifications, replace the gear or the crankshaft.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

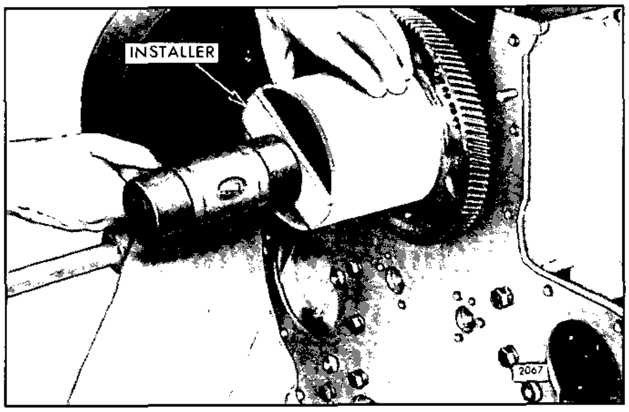


Fig. 2 – Installing Crankshaft Timing Gear Using Installer J 7557

1. If removed, install the Woodruff key in the keyway in the crankshaft.

2. Start the timing gear over the end of the crankshaft with the timing marks on the outer rim of the gear facing out and the keyway in the gear in alignment with the Woodruff key in the crankshaft.

3. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. Place a heavy hammer against the head of the bolt in the front end of the crankshaft. Place installer J 7557 against the rear face of the timing gear and drive the gear up against the shoulder on the crankshaft (Fig. 2).

5. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.

6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

8V-53 ENGINE

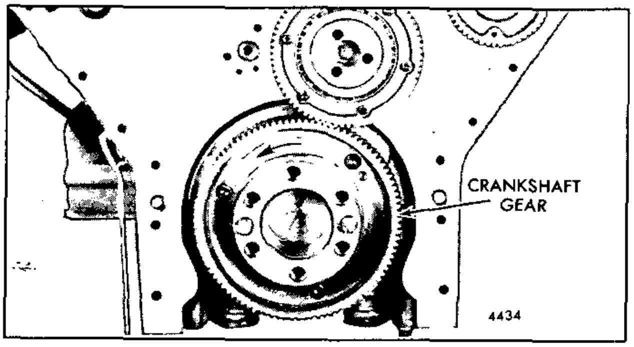


Fig. 3 – Crankshaft Timing Gear Mounting *(R.H. Rotation Engine Shown)*

The crankshaft timing gear on an 8V-53 engine is keyed and fastened to the crankshaft with three 3/8"-24 x 3/4" socket head bolts (Fig. 3).

Since the camshafts must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft gears (refer to Section 1.7.1).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft timing gear is a .001" to .003" press fit on the crankshaft. The crankshaft diameter at this point is 4.060" to 4.061". Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.

2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its *original* position.

3. Remove the three socket head bolts securing the gear to the crankshaft.

4. Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then, remove the gear with a suitable puller (J 4871).

Inspection

Clean the gear with fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection *and do not exceed 40 psi (276 kPa) air* pressure.**

Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also, check the other gears in the gear train.

Install Crankshaft Timing Gear

1. If removed, install the Woodruff key in the keyway in the crankshaft.

2. Start the timing gear over the end of the crankshaft with the timing marks on the outer rim of the gear facing out and the keyway in the gear in alignment with the Woodruff key in the crankshaft.

3. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

   When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. Start the three 3/8"-24 socket head bolts into the crankshaft. Then, slowly draw the gear tight against the shoulder on the crankshaft by tightening the bolts uniformly to 35-39 lb-ft (47-53 N·m) torque.

5. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.

6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

4–53 AND 6V–53 ENGINES

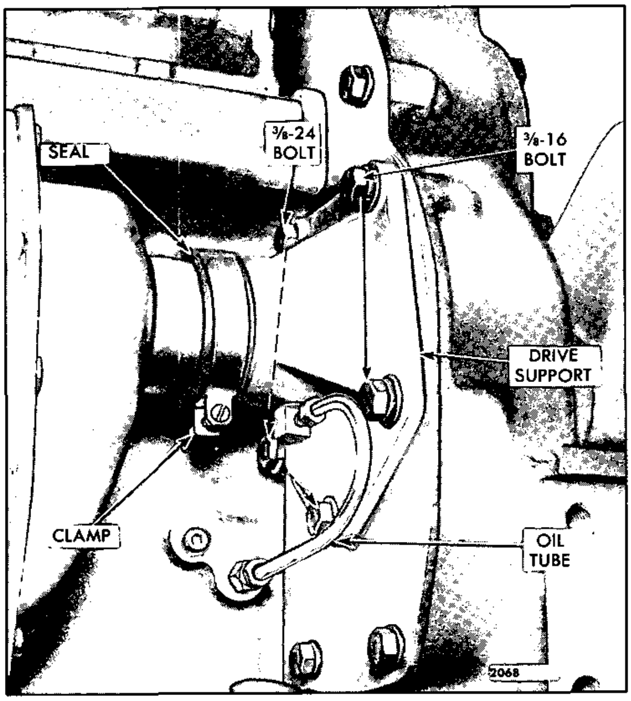


Fig. 1 – Blower Drive Support Mounting on 4–53 In–line Engine

The blower drive gear is driven by the camshaft gear (4–53 engine) or the left–bank camshaft gear (6V–53 engine). The gear is keyed and pressed on a shaft which is supported in the blower drive support. This support, on a 4–53 engine, is attached to the rear end plate on the blower side of the engine (Fig. 1). On a 6V–53 engine, the blower drive support is mounted on the flywheel housing (Fig. 2).

Effective with engine serial numbers 4D–201579 and 6D–220736, new carbonitride–hardened blower drive shaft and a new steel induction–hardened blower coupling cam are being used in naturally aspirated and turbocharged engines. Carbontride hardening results in added resistance to shaft and coupling spline wear. To distinguish the new shafts from the former, one end of each new shafts is stamped with the letter "H". The non–counterbored face of the new cam is stamped with the letter "S". The former and the new components are not interchangeable, and only the new components will be serviced.

To reduce the level of engine noise in the Series 53 engines, the pitch and pressure angle of the gear train and accessory drive gears has been changed (refer to Section 1.7.1).

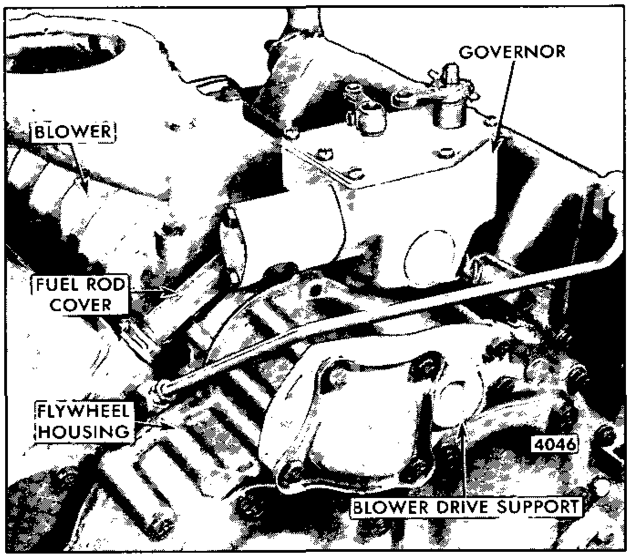


Fig. 2 – Blower Drive Support Mounting on 6V–53 Engine

Service the blower drive support on a 6V engine as outlined in Section 2.7.1.1. The following procedures apply only to the 4–53 engine.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3–53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D–193516 and 6D–229616.

Remove and Install Blower Drive Shaft

1. Remove the air inlet housing from the blower (refer to Section 3.3).
2. Refer to Fig. 1 and loosen the blower drive seal clamp.
3. Slide the clamp and seal off of the blower drive support.
4. Remove the four blower–to–block bolts. Then, carefully lift the blower away from the blower drive support and the cylinder block so the serrations on the blower drive shaft are not damaged.
5. Withdraw the blower drive shaft from the blower drive support.
6. Install the shaft by reversing the removal procedure.

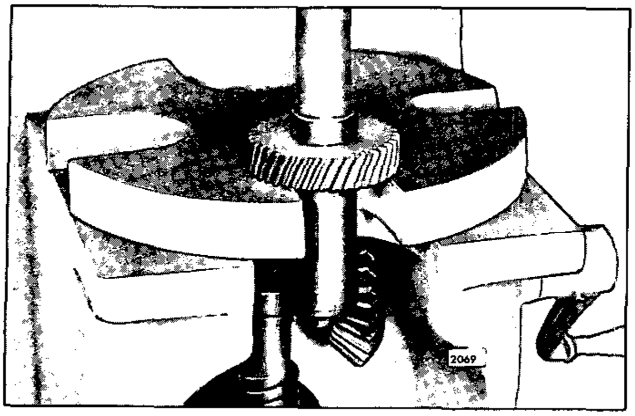


Fig. 3 – Pressing Blower Drive Gear From Shaft

Remove Blower Drive Support

1. Remove the blower and the blower drive shaft as outlined above.
2. Disconnect the lubricating oil tube from the blower drive support (Fig. 1).
3. Remove the blower drive support attaching bolts.
4. Tap the blower drive support to loosen it, then carefully withdraw the support from the rear end plate so the blower drive gear teeth will not be damaged.

Disassemble Blower Drive Support

1. Remove the snap ring and the thrust washer from the shaft.
2. If there are burrs on the edges of the snap ring groove, remove them with a stone. Then, withdraw the gear and shaft from the support.
3. Support the blower drive gear in an arbor press (Fig. 3).
4. Place a short 1-1/8" diameter brass rod on the end of the shaft and press the shaft out of the gear.

Inspection

Thoroughly clean the parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection *and do not exceed 40 psi (276 kPa) air* pressure.**

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also, check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and the support should not be less than .0035" (with new parts) or more than .007" (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the shaft is inserted into the blower drive gear shaft, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer, if necessary. The thickness of a new blower drive support thrust washer is .093" to .103".

Inspect the gear teeth for evidence of scoring, pitting, burning or wear. If necessary, install a new gear.

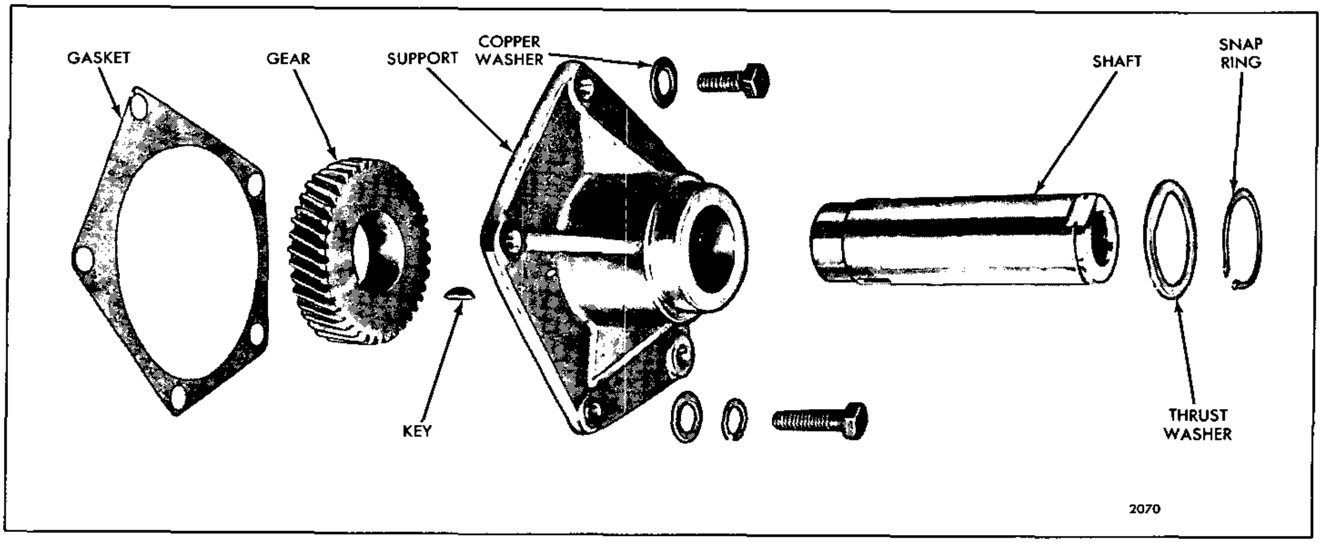


Fig. 4 – Blower Drive Gear and Support Assembly Details and Relative Location of Parts (In-line Engine)

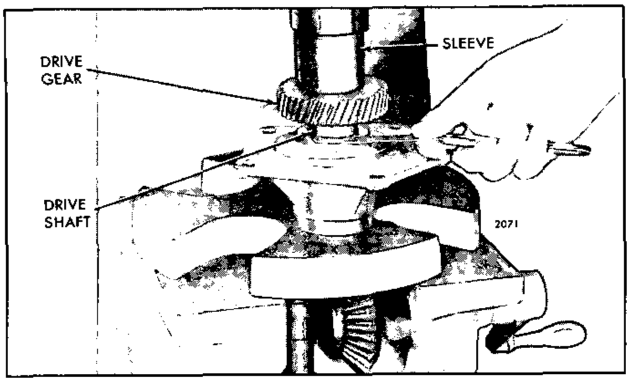


Fig. 5 – Pressing Blower Drive Gear On Shaft

Assemble Blower Drive Support

Refer to Fig. 4 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the blower drive gear shaft with clean engine oil and insert the shaft into the blower drive support.
2. Assemble the thrust washer and the snap ring on the shaft.
3. Install the key in the shaft, if it was removed.
4. Place the shaft and support in an arbor press.
5. Position the gear on the shaft so the keyway in the gear is in alignment with the key in the shaft. Then, place a sleeve on the gear and press the gear on the shaft until the clearance between the gear and support is .004" to .012" (Fig. 5).

Install Blower Drive Support

1. Affix a new blower drive support gasket to the cylinder block rear end plate.
2. Install the blower drive support assembly by reversing the removal procedure.
3. Tighten the 3/8"–24 support–to–end plate bolts (with copper washers) and the 3/8"–16 support–to–flywheel housing bolts (with plain washers and lock washers) to 35 lb–ft (47 N·m) torque.

8V–53 ENGINE

The blower drive gear is driven by the right–bank camshaft gear. The drive gear is pressed on a shaft which is supported in the blower drive support. The blower drive support assembly is attached to the blower rear end plate and the forward face of the cylinder block end plate.

The blower drive support bearing receives oil under pressure from the horizontal oil passage in the blower rear end plate which leads to the oil passage in the blower drive support.

Remove And Install Blower Drive Shaft

1. If an air compressor is attached to the rear right–hand face of the flywheel housing, disconnect and remove it from the flywheel housing.
2. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.
3. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.
4. Pull the blower drive shaft out of the blower drive hub and cam. If necessary, use a pair of small nose pliers.
5. Install the blower drive shaft by reversing the removal procedure.

Remove Blower Drive Support

1. Remove the blower, governor and drive support assembly from the engine as outlined under *Remove Blower* in Section 3.4.1.
2. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support to the blower rear end plate.
3. Tap each end of the blower drive support with a plastic hammer to loosen it from the gasket and dowel pins. Then, remove the drive support assembly and gasket.

Disassemble Blower Drive Support

Refer to Figs. 6 and 7 and disassemble the blower drive support as follows:

1. Remove the thrust washer retaining snap ring from the blower drive gear shaft with a pair of snap ring pliers. Then, remove the thrust washer from the shaft.

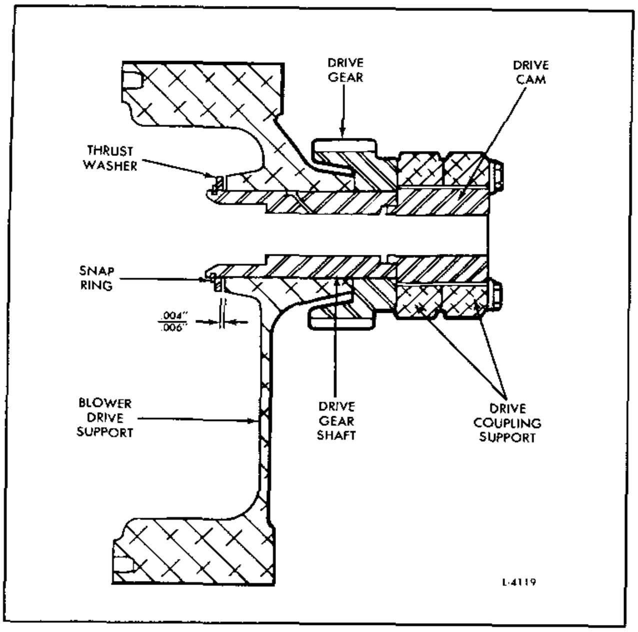


Fig. 6 – Blower Drive Support Assembly

2. If there are any burrs on the edges of the snap ring groove, remove them with a fine stone. Then, withdraw the drive gear and shaft from the support.

3. Support the blower drive gear and shaft, rear face of the gear up, on two wood blocks on the bed of an arbor press.

4. Place a short brass rod on the end of the shaft and press the drive gear shaft out of the gear. Catch the shaft by hand to prevent damage to the shaft.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also, check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and the support should not be less than .002" (with new parts) or more than .007" (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the blower drive shaft is inserted into the blower drive cam and drive hub, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer, if necessary. The thickness of a new blower drive support thrust washer is .119" to .121".

Inspect the gear teeth for evidence of scoring, pitting, burning or wear. If necessary, install a new gear.

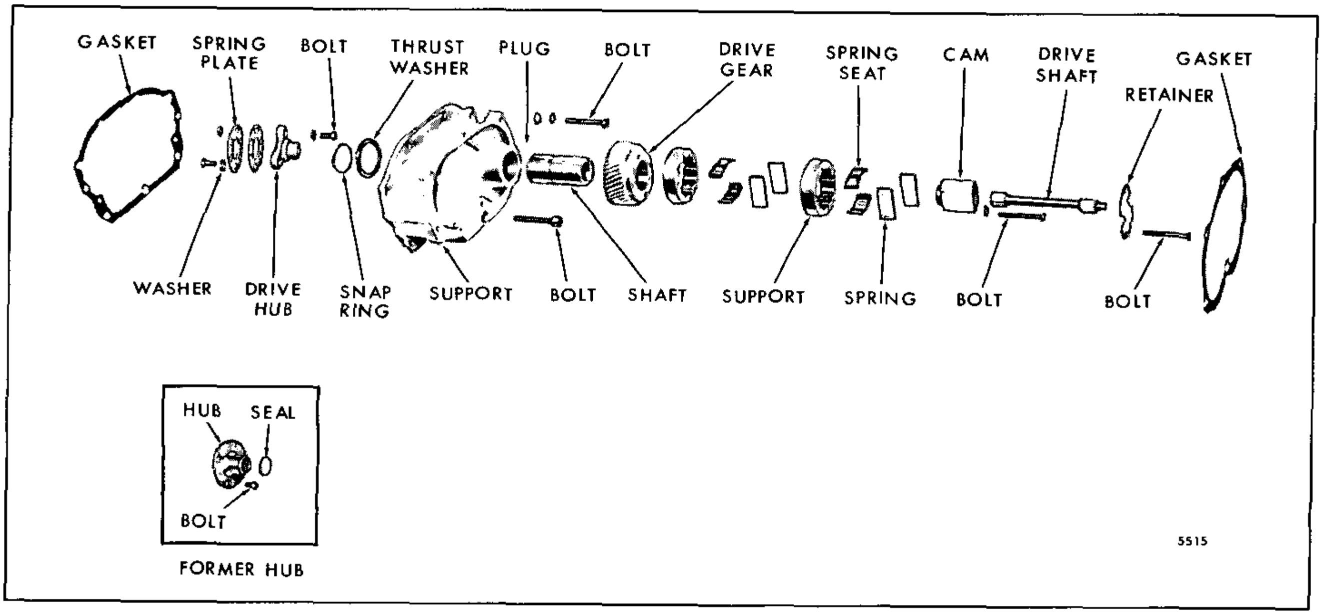


Fig. 7 – Blower Drive Support Details and Relative Location of Parts (8V–53 Engine)

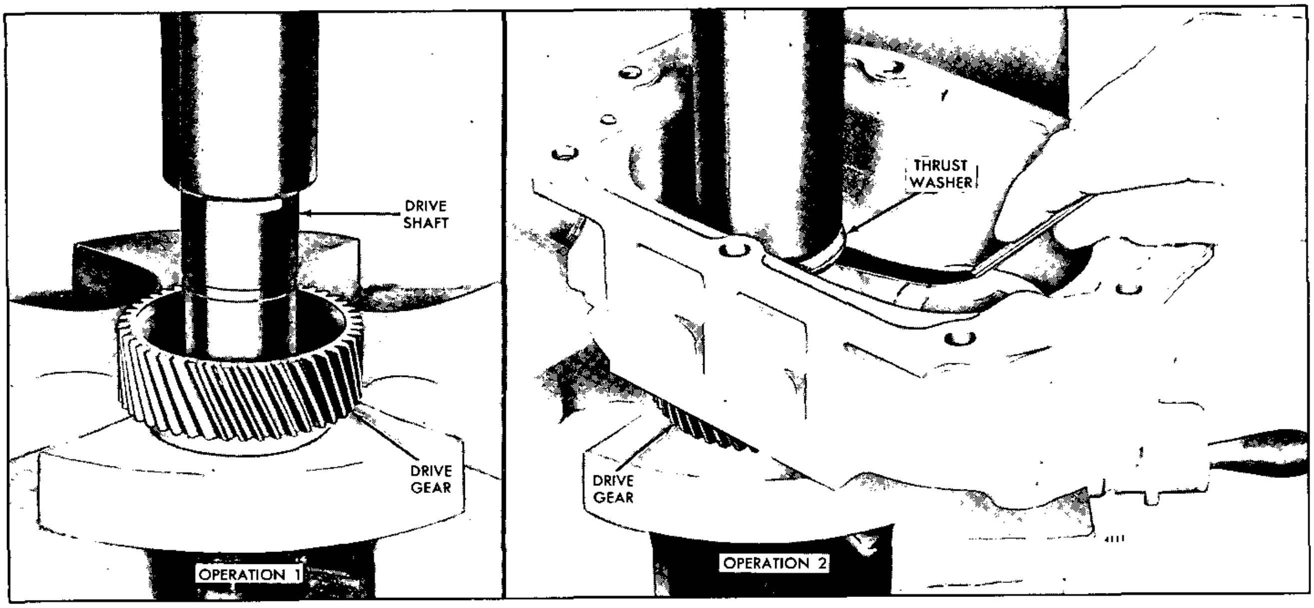


Fig. 8 – Installing Blower Drive Gear Shaft in Drive Gear

Assemble Blower Drive Support

Refer to Figs. 6 and 7 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the drive gear end of the blower drive gear shaft with engine oil. Then, start the shaft straight into the shaft bore in the drive gear from the recessed side.

2. Place the blower drive gear and shaft on the bed of an arbor press (Fig. 8, Operation 1). Then, press the shaft straight into the drive gear approximately one half inch.

3. Lubricate the blower drive gear shaft with engine oil. Then, insert the shaft into the shaft bore in the support.

4. Place the thrust washer, oil groove side facing the support, on the blower drive gear shaft. Then, install the snap ring in the groove in the shaft.

5. Support the blower drive gear, shaft and support on the bed of an arbor press (Fig. 8, Operation 2). Then, press the drive gear shaft into the drive gear until the clearance between the thrust washer and the support is .004" to .012" (Fig. 6).

Install Blower Drive Support

1. Affix a new blower drive support gasket to the forward face of the support.

2. Place the blower drive support assembly over the two dowel pins in the blower rear end plate and against the gasket.

3. Install the six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20–24 lb-ft (27–33 N·m) torque.

4. Install the blower, governor and drive support assembly on the engine as outlined under *Install Blower* in Section 3.4.1.

ACCESSORY DRIVES

Accessory drives have been provided at the rear of the engines to accommodate both gear–driven and belt–driven accessories.

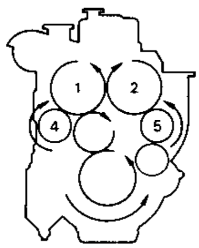
For the possible accessory drive locations and rotation of the drive at a particular position, refer to Fig. 1.

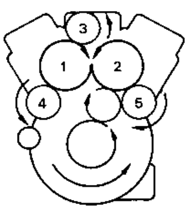
The drive for direct gear–driven accessories, such as air compressors or hydraulic pumps, consists of a drive hub, coupling and drive plate (Fig. 2) or a spacer, drive plate, drive coupling and hub (Fig. 3).

On certain 4–53 engines, the spacer has been eliminated and a drive coupling 1.940″ long and a drive disc .560″ wide is used.

The drive plate and spacer, when used, are bolted to the camshaft or balance shaft gear. The accessory is bolted to the flywheel housing and driven by a drive hub keyed to the accessory shaft and splined to the coupling which is splined to the drive plate attached to the camshaft or balance shaft gear. The current drive coupling, shown in Fig. 3, has 21 external teeth; the former coupling had 23 external teeth.

Belt–driven accessories, such as battery–charging generators or air compressors, are driven off the camshaft or balance shaft gears by a drive hub and pulley (Fig. 4), or a spacer, accessory drive plate, accessory drive shaft, accessory drive retainer assembly and pulley (Fig. 5).





ACCESSORY DRIVE POSITION	DRIVE RATIO
INLINE ENGINE	
1	1:1
2	1:1
4 BLOWER	2.47:1
GOV.	1.98:1
5 BLOWER	2.47:1
GOV.	1.98:1
V-ENGINE	
1	1:1
2	1:1
3	*2.47:1
4	1.98:1
5	1.98:1
*2.20:1 ON 8V ENGINE	

L – 5325

Fig. 1 – Accessory Drive Locations

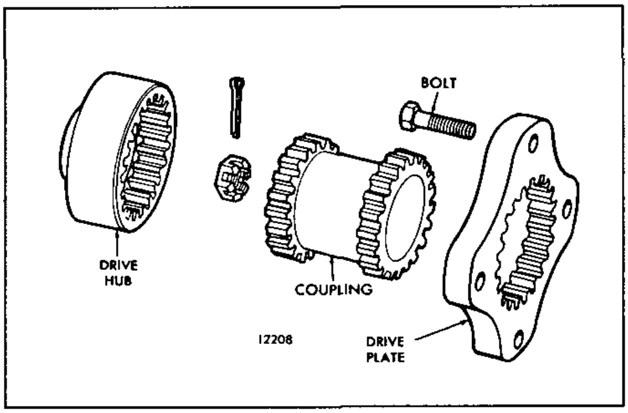


Fig. 2 – Air Compressor Drive

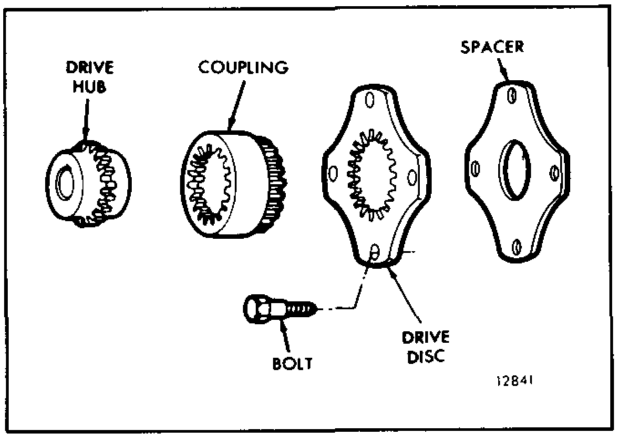


Fig. 3 – Hydraulic Pump Drive

In the first arrangement, illustrated in Fig. 4, the drive hub is bolted to the camshaft or balance shaft gear. The oil seal retainer is bolted to the flywheel housing and the pulley is keyed to the drive hub shaft which extends through the oil seal retainer.

In the second arrangement, shown in Fig. 5, the spacer and accessory drive plate are bolted to the camshaft or balance shaft gear. The accessory drive shaft is splined to the drive plate at one end and supported by a bearing in the accessory drive retainer at the other end. The accessory drive retainer, which also incorporates an oil seal, is bolted to the flywheel housing. The pulley is keyed to the drive shaft which extends through the drive retainer assembly.

Remove Accessory Drive

Remove the direct gear–driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

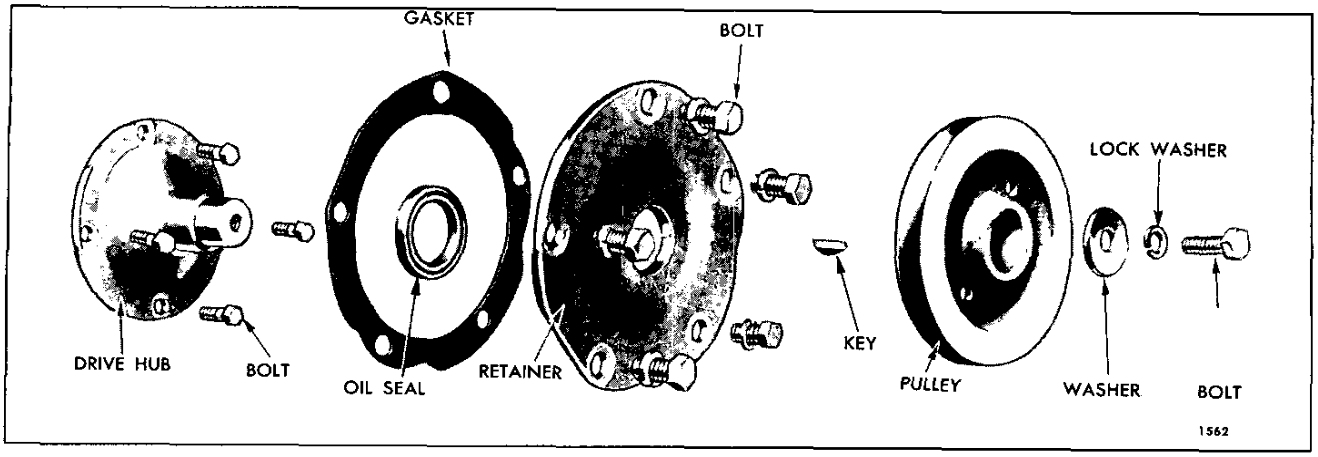


Fig. 4 – Components of Accessory Drive for Belt–Driven Accessory (Drive Hub Type)

2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.

3. Remove the drive coupling.

4 Remove the drive hub from the accessory shaft, if necessary.

5. Place a clean, lintless cloth in the flywheel housing opening, underneath the accessory drive plate, to prevent bolts from accidentally falling into the gear train. Remove the lock wires, if used. Then remove the four bolts (and lock washers, if used) and remove the accessory, the drive plate and the spacer, if used.

Remove the drive assembly for a belt–driven type accessory as follows:

1. Remove any external piping or connections to the accessory.

2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and accessory.

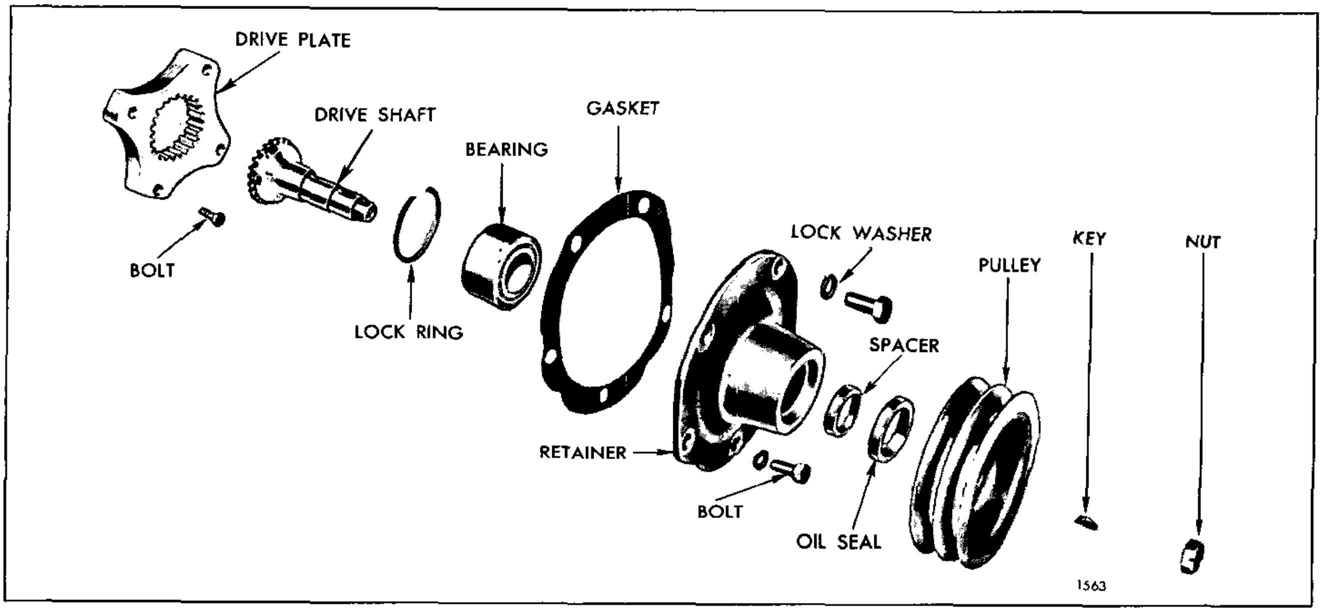


Fig. 5 – Components of Accessory Drive for Belt–Driven Accessory (Drive Plate Type)

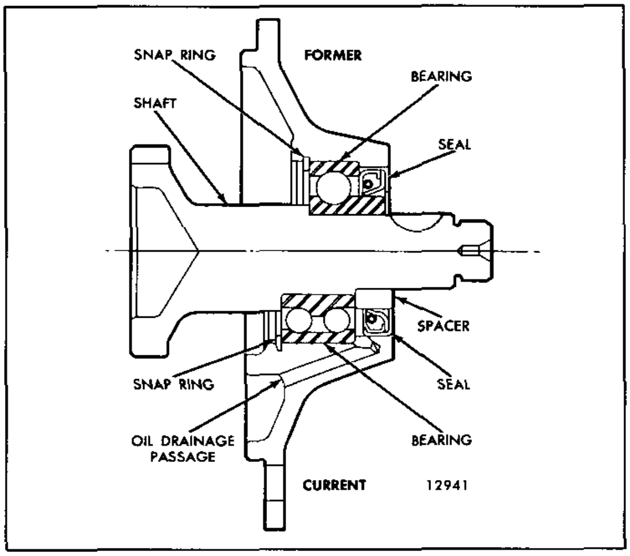


Fig. 6 – Former and Current Drive Plate Type Accessory Drive

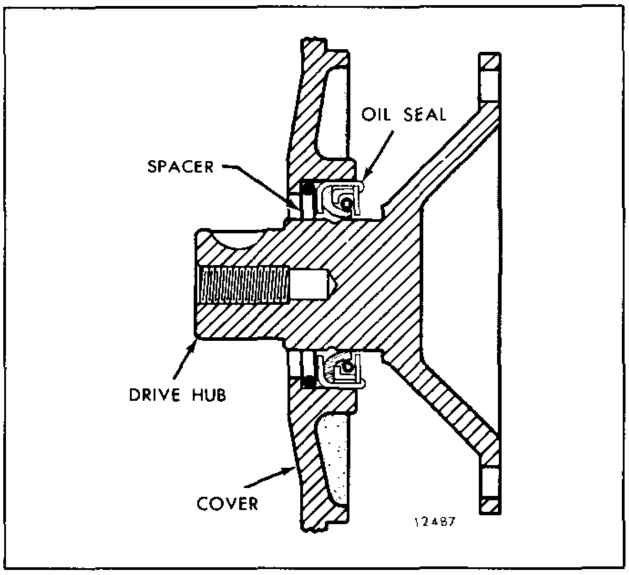


Fig. 7 – Location of Oil Seal Spacer

3. Remove the bolt and washer (Fig. 4), or nut (Fig. 5), retaining the pulley on the drive shaft.

4 Use a suitable gear puller to remove the pulley from the drive shaft. Remove the Woodruff key.

5. Remove the five bolts and lock washers which attach the drive retainer assembly to the flywheel housing. Remove the retainer assembly.

6. Remove the accessory drive shaft, drive plate and spacer (Fig. 5), or drive hub (Fig. 4), in a manner similar to that outlined in Step 5 under removal of the direct gear–driven type accessory drive.

7. Remove the snap ring and ball bearing from the accessory drive shaft retainer assembly shown in Fig. 5.

Inspection

Clean the accessory drive parts with clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the gear teeth of the drive shaft, drive coupling, drive hub or drive plate for wear. If worn excessively, replace them with new parts.

Inspect the ball bearing used to support the accessory drive shaft shown in Fig. 5. Wash the bearing in clean fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the outside of the bearing clean, then hold the inner race and revolve the outer race slowly by hand. If the bearing is worn or does not roll freely, replace the bearing. Inspect the accessory drive hub, shown in Fig. 4, for grooving at the area of contact with the lip of the oil seal. If the hub is grooved to a point where the effectiveness of the oil seal is lost, a ring type oil seal spacer is available which serves to reposition the seal, thus providing a new sealing surface for the lip of the seal (Fig. 7).

Install Accessory Drive

1. Remove old gasket material from the flywheel housing. Use care so that no gasket material falls into the gear train compartment.

2. Insert a clean, lintless cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate and spacer (if used), or the accessory drive hub, with the tapped holes in the camshaft or balance shaft gear. Then secure the plate and spacer, or drive hub, with four bolts (and lock washers or lock wire, if used). Remove the cloth from the flywheel housing opening.

3. If a gear–driven accessory is used as shown in Figs. 2 and 3, install the accessory drive coupling. When replacing the drive hub on the accessory shaft, drive

the hub squarely on the shaft (refer to Section 12.4). Then proceed as follows:

a. Place a new gasket on the flange and align the holes in the gasket with the bolt holes in the flange. Use a light coat of grease to retain the gasket in position.

b. Place the accessory in position against the flywheel housing, rotating it, if necessary, to align the teeth of the accessory hub with those in the drive coupling. Secure the accessory to the flywheel housing with five bolts and lock washers.

4. If the accessory drive shown in Figs. 5 or 6 is used, assemble as follows:

a. Install the accessory drive plate and spacer as outlined in Steps 1 and 2 above.

b. Place the drive shaft retainer on the bed of an arbor press, with the mounting flange side up. Press the double-row ball bearing straight in until the bearing contacts the shoulder in the bore of the retainer. Install the snap ring.

On former accessory drives (Fig. 6), install the bearing with the protruding face of the inner race towards the retainer.

c. Turn the retainer over and press the oil seal into the bore of the retainer with the lip of the seal toward the bearing.

d. Turn the retainer over again, bearing side up, and press the accessory drive shaft in the bearing until the shoulder on the shaft contacts the bearing.

e. Apply a light coat of grease to the mounting flange of the retainer and place a new gasket in position against the flange. Align the holes in the gasket with the bolt holes in the flange.

f. Place the retainer and drive shaft assembly against the flywheel housing, rotating the shaft slightly, if necessary, to permit the teeth of the drive shaft to mesh with the teeth in the drive plate. Secure the retainer assembly to the flywheel housing with five bolts and lock washers.

g. On current accessory drives, install the spacer over the shaft and against the bearing.

h. Install the Woodruff key in the drive shaft. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

i. Thread the 3/4"–16 pulley retaining nut on the end of the drive shaft and tighten it to 120–140 lb–ft (163–190 N·m) torque.

j. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

5. Assemble the accessory drive shown in Fig. 4 as follows:

a. Press a new oil seal in the oil seal retainer, if the seal was removed.

b. Coat the mounting flange of the retainer lightly with grease and place a new gasket against the flange. Align the holes in the gasket with the bolt holes in the flange.

c. With the accessory drive hub in place (see Step 2 above), slip the retainer and oil seal assembly over the end of the shaft. Use care not to damage the oil seal. Secure the retainer to the flywheel housing with five bolts and lock washers.

d. Install the Woodruff key. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

e. Install the washers and the pulley retaining bolt and draw the bolt up tight.

f. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

ENGINE FRONT COVER (Upper)

In–Line and 6V Engines

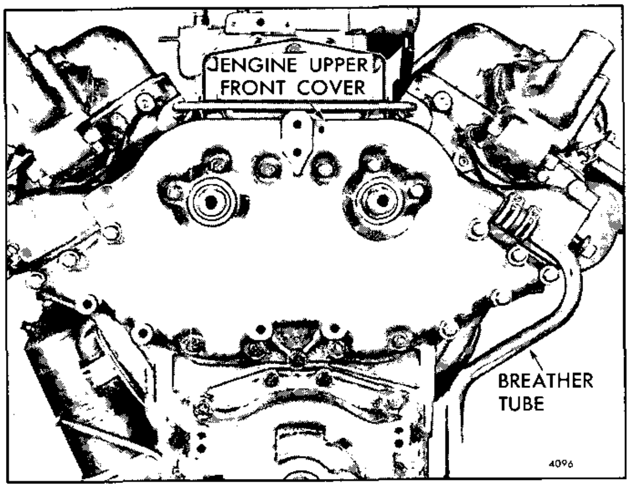


Fig. 1 – 6V Engine Upper Front Cover Mounting

The upper engine front cover is mounted against the cylinder block at the upper front end of the engine. On a 6V engine, the crankcase is ventilated through a breather tube connected to the cover (Fig. 1). The camshaft and balance shaft oil seals (In–line engine) or camshaft oil seals (6V engine) are pressed into the cover.

● To reduce operating noise levels, the upper front covers on 3, 4, and 6V–53 turbocharged industrial engines have been changed, effective with unit serial numbers 3D0197864, 4D0211728, and 6D0231643. On 3 and 4-53T units a new cast iron upper front cover with strategically placed cast-in ribs has replaced the former aluminum cover. On 6V-53T engines the current cast iron covers have been revised by the addition of cast-in ribs on their inside walls. The ribs make the covers less prone to vibration. Interchangeability is not affected, and only the new 3 and 4-53T cover and the revised 6V-53T cover will be available to service Series 53 turbocharged industrial engines.

Remove Cover

When necessary, the oil seals may be removed without removing the upper front cover. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars. Install the new seals with installer J 9790.

If necessary, remove the engine cover as follows:

1. Remove the various parts and subassemblies from the engine as outlined in their respective sections of this manual.
2. Remove the pulleys from the front end of the camshaft and balance shaft (In–line engine) or the camshafts (6V engine). Refer to Section 1.7.2.
3. Remove the upper front cover–to–cylinder block attaching bolts.
4. Tap the cover and dowel pin assembly away from the cylinder block.
5. Remove the Woodruff keys and oil seal spacers from the shafts.
6. Remove all traces of the old gasket material from the cylinder block and cover.

Inspection

Check the oil seals and the spacers for wear or damage. Replace them if necessary.

On a 6V engine, remove, clean and reinstall the wire mesh pad (element) in the upper front cover.

Remove Oil Seals

1. Support the inner face of the cover on wood blocks at least one inch thick to protect the dowel pins in the cover.
2. Drive the oil seals out of the cover.

Install Oil Seals

1. Support the inner face of the cover on wood blocks.
2. If the outside diameter of the oil seal is not pre–coated with sealant, coat the bore in the cover with non–hardening sealant.

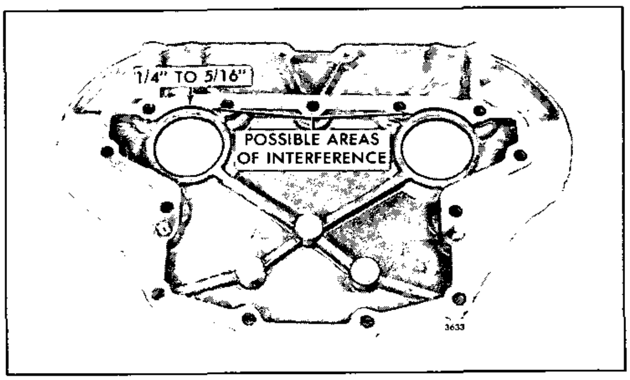


Fig. 2 – In–Line Engine Upper Front Cover

3. Position a new oil seal in the cover with the lip of the seal pointing toward the inner face of the cover. Keep the lip of the oil seal clean and free from scratches.

4. Press the seal into the cover with installer J 9790 until the seal is flush with the bottom of the counterbore.

5. Install the second oil seal in the same manner.

6. Remove excess sealant from the cover and the seals.

Install Cover

1. Affix a new gasket to the cover.

2. Install the cover on the engine and secure it with bolts and lock washers. Tighten the bolts to 35 lb–ft (47 N·m) torque.

3. Apply cup grease to the outside diameter of the oil seal spacers, then slide them on the shafts.

   Current engines use an oil slinger between the oil seal spacer and the shoulder on the camshaft and between the spacer and the end bearing on the balance shaft (In–line engine). *Addition of the oil slinger improves* sealing by reducing the amount of oil in the area of the oil seals.

   If oil slingers are installed on in–line engines built prior to serial numbers 2D–9278, 3D–573 and 4D–944, check the distance from the holes to the gasket flange (Fig. 2). If necessary, machine or grind the cover to provide sufficient clearance for the slingers.

4. Install a Woodruff key in each shaft.

5. Install the pulleys on the shafts.

6. Install and tighten the pulley retaining nuts to 300–325 lb–ft (407–441 N·m) torque.

SHOP NOTES - TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CHECKING BEARING CLEARANCES

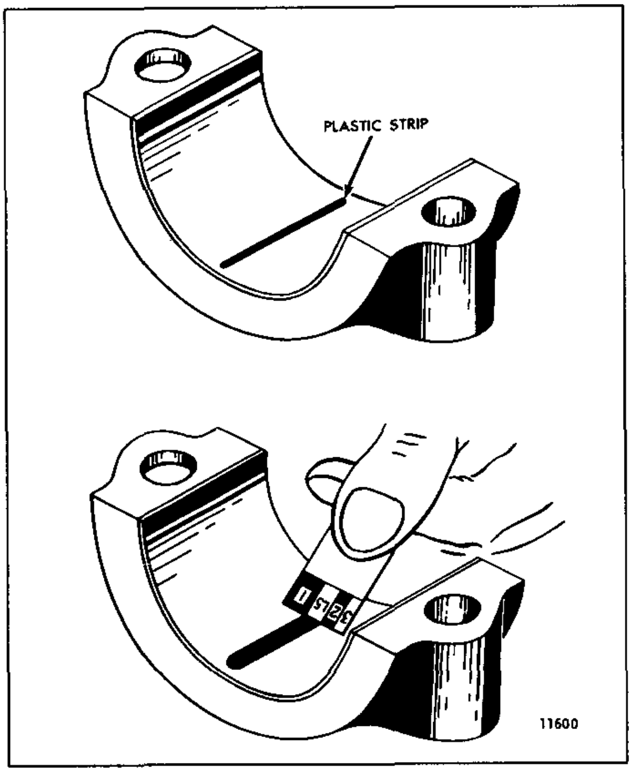


Fig. 1 – Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006" and type PB-1 (blue) has a range of .004" to .009".

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal.

   When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and flywheel, can be eliminated by supporting the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 1).

3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.

5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

IN-FRAME OVERHAUL

Polyethylene plastic plugs (J 34697) help prevent solvent and debris from entering the crankcase while cleaning the airbox during in-frame overhaul or cylinder kit replacement.

CAMSHAFT CUP PLUG INSTALLATION

When an oil leak occurs at the drive plug area in the front end of the camshaft, install a cup plug in the end of the camshaft rather than removing and replacing the drive plug. It is not necessary to remove the camshaft from the engine when installing the cup plug.

Install the cup plug as follows:

1. Clean the hole in the front end of the camshaft and apply Permatex No. 1 sealant, or equivalent, to the outer diameter of the cup plug.

2. Install the plug to a depth of .180"–.210" with tool J 24094.

CYLINDER BLOCK LINE BORING

To line bore the main bearing bores, install the main bearing caps in the block and torque the bolts with their hardened washers to 120–130 lb-ft (163–177 N·m). The main bearing cap bolts are specially designed and must not be replaced by ordinary bolts. There should be a minimum of .0002" (In-line) or .0003" (V-engine) interference fit between the main bearing block saddle and the main bearing caps. If not, the cap must be replaced.

The tolerences shown below must be maintained during the reboring operation. If tolerances are not held, severe gear train damage may occur during engine operation.

1. All bores must be concentric within .001" TIR. If the bore cannot be held to .001" TIR, the block must be scrapped.

2. The surfaces from which all critical dimensions are measured for line boring are the dowel locating holes (.6245"–.6255" in diameter) at each end of the right pan rail, looking from the gear train end of the cylinder block. The crankshaft centerline is 4.239" to 4.241" in from the centerline of the dowel locating holes and 4.5985" to 4.6015" up from the pan rail surface.

3. Bore diameters for standard and oversized main bearing shells are shown in the following table:

Main Bearing	Main Bearing Bore Diameter
Standard (InLine 53)	3.251" - 3.252"
Standard (V-53)	3.751" - 3.752"
.010" Oversize (InLine 53)	3.261" - 3.262"
.010" Oversize (V-53)	3.761" - 3.762"
.020" Oversize (InLine 53)	3.271" - 3.272"
.020" Oversize (V-53)	3.771" - 3.772"

TABLE 1

4. The straightness of the finished bore must not vary more than .001" from end to end in the cylinder block.

5. After boring the block, stamp all main bearing caps to show they have been bored oversize and the amount (.010" or .020").

After installing oversize O.D. main bearing shells, always check bearing clearances before putting the engine back in service. Use the procedure found in this section.

• WELDING ENGINE CYLINDER HEADS

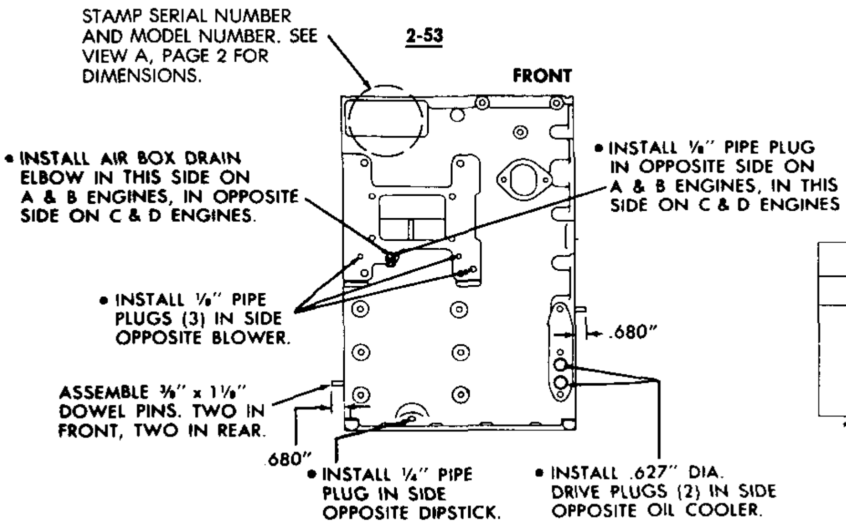
The welding of series 53 cylinder heads is not recommended. The welding of cylinder heads has been used as a salvage procedure for several years. As a salvage procedure, the resultant product has not been considered as good as a new casting.

REUSING CROSSHEAD PISTON ASSEMBLY COMPONENTS

Components of the piston assemblies can, in certain instances, be reused. Undamaged piston pins, crowns and bushings that meet dimensional limits for used parts can be reused if installed within the same piston assembly from which they were removed.

The crown, pin and bushing of a crosshead piston assembly should be considered as matched. If a crown is replaced, the piston pin and bushing must also be replaced. The reason for this is that the bushing takes the shape of the saddle area of the piston dome during engine operation. Installing a used bushing in a new crown can result in uneven piston pin loading and possible piston pin damage. If a bushing needs replacement, a new pin must also be used. Conversely, if a new pin is required, the bushing must also be replaced. Before reusing any crosshead piston assembly components, see wear limits in this Section.

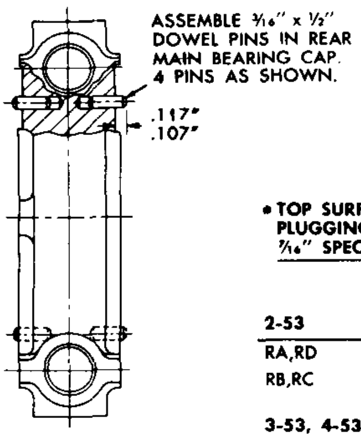
CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)



STANDARD PIPE PLUG TORQUE*		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

*CAUTION — Do Not Over Torque Teflon Wrapped Pipe Plugs.

CUTAWAY VIEW OF REAR MAIN BEARING CAP



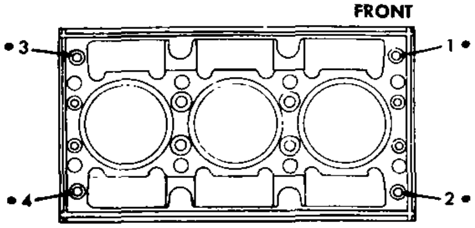
NOTES

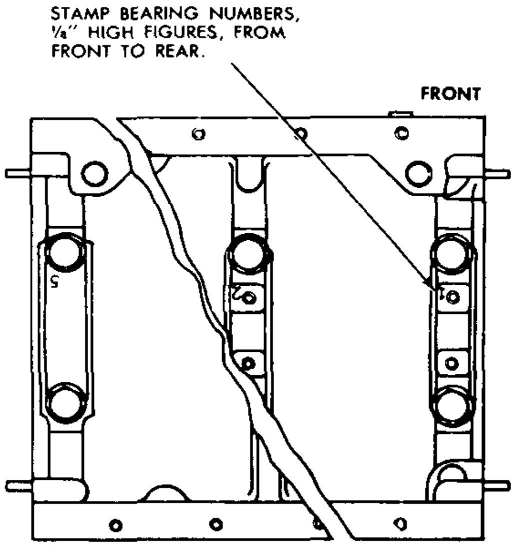
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

• **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

• TOP SURFACE PLUGGING INSTRUCTIONS 7/16" SPECIAL CUP PLUG

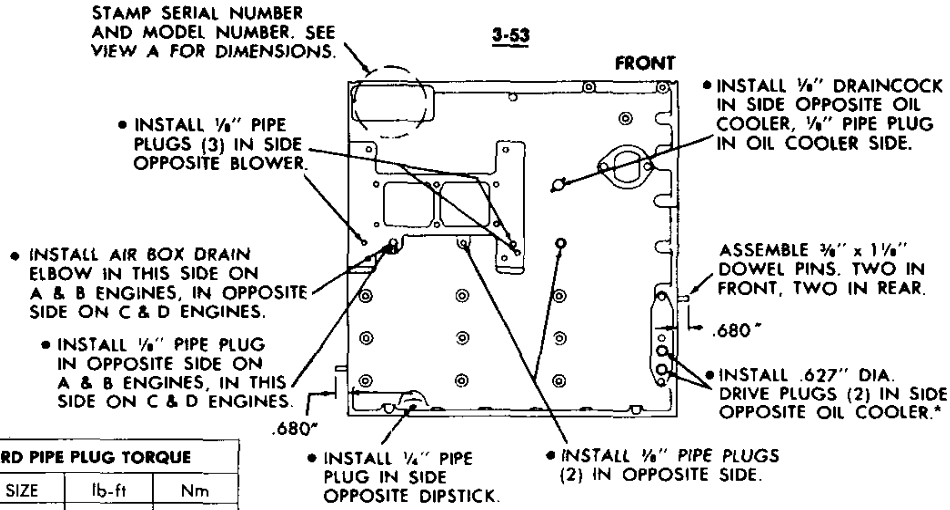
	HOLES PLUGGED 1	2	3	4
2-53				
RA,RD		X	X	X
RB,RC	X	X	X	
3-53, 4-53				
RA,LA,RD,LD		X		X
RB,LB,RC,LC	X		X	





REV. 9-77

CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN–LINE ENGINES)

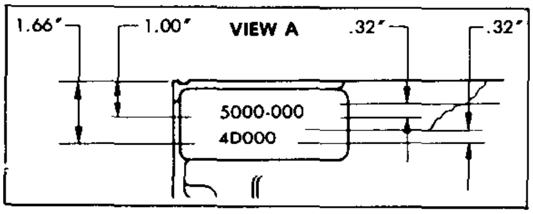


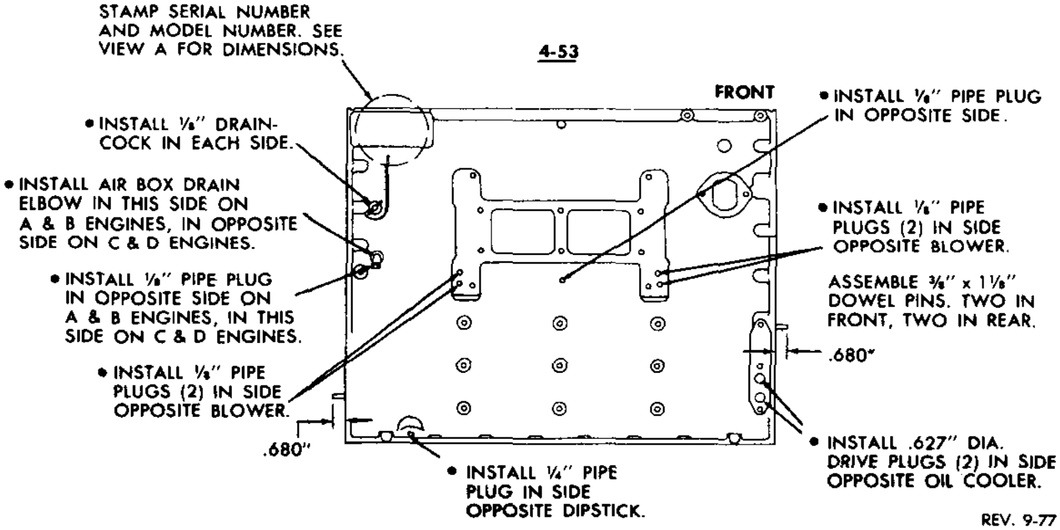
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

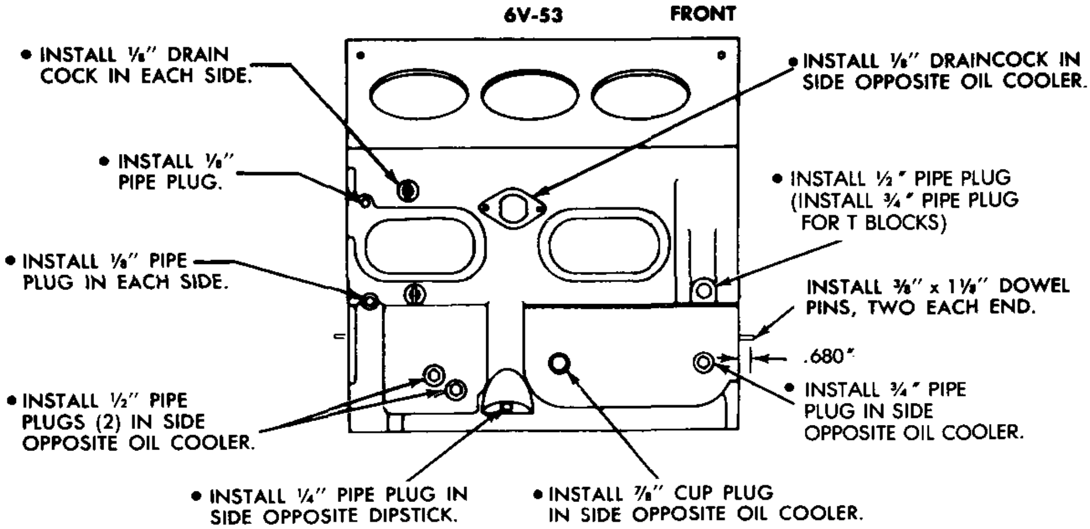
• **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**





*Some Engine Require .751" Drive Plug at this Location.

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)



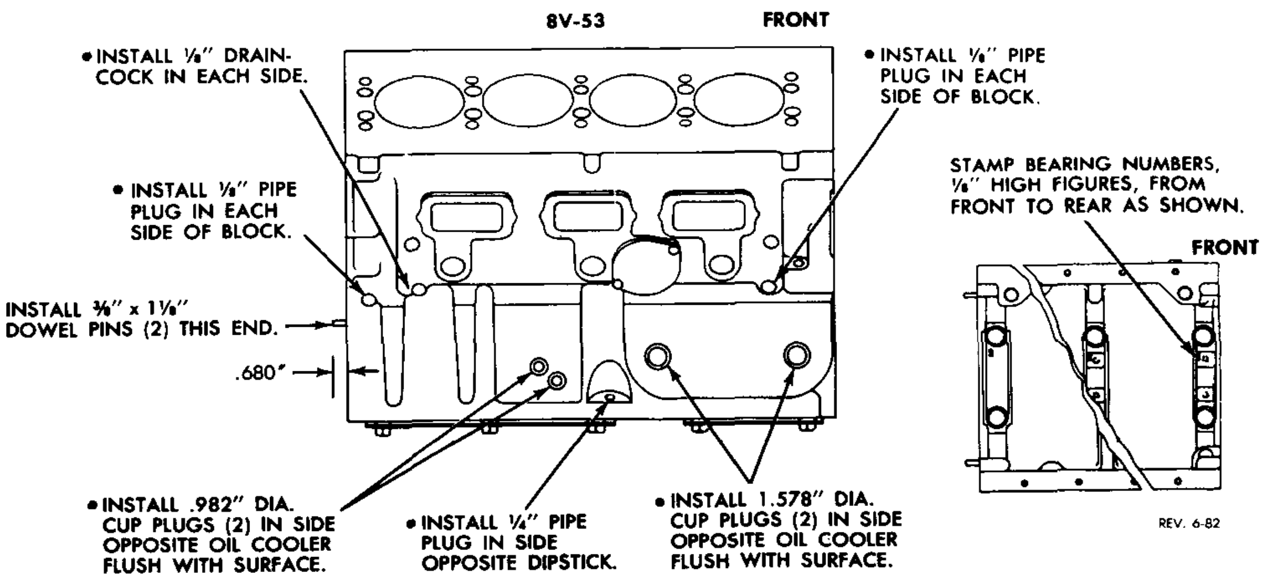
NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

STANDARD PIPE PLUG TORQUE

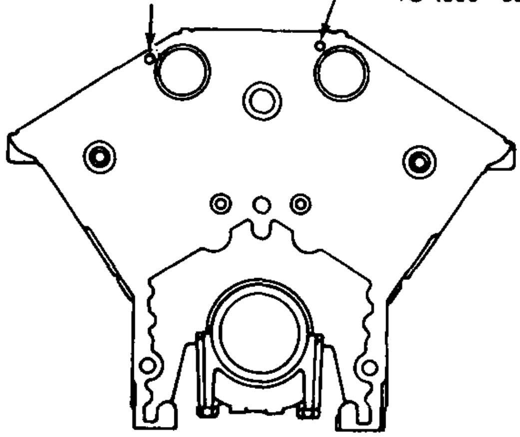
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50



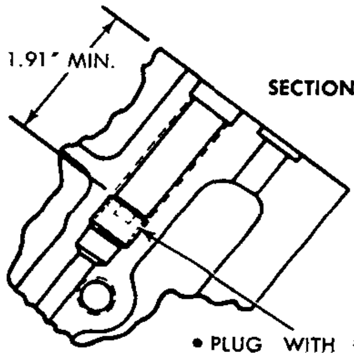
CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)

INSTALL 5/16" x 5/16" DOWEL PIN AT EACH END. (COPPER-FLASHED FOR 8V-53, PLAIN FOR 6V-53) FLUSH TO .020" BELOW SURFACE.

• INSTALL 5/16" SPEC. CUP PLUG, FRONT AND REAR ON 8V-53, REAR ONLY ON 6V-53 FLUSH TO .030" BELOW SURFACE.



REAR



SECTION A-A

• PLUG WITH 3/8" SOCKET CUP SET SCREW RIGHT AND LEFT BANK AT REAR 8V-53 ONLY

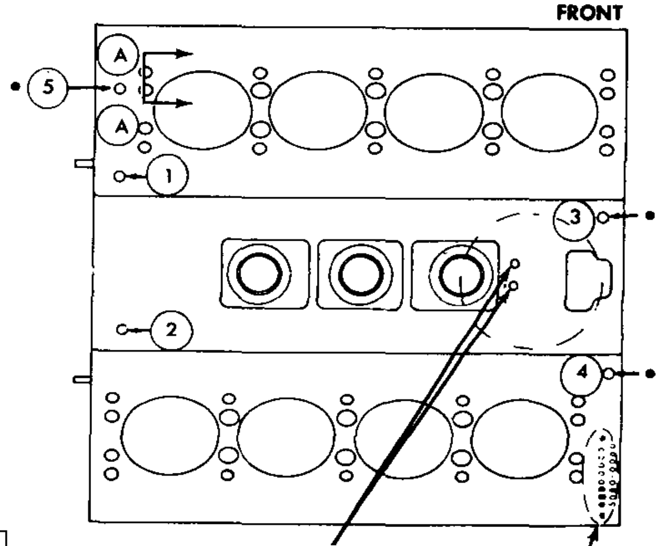
TOP SURFACE PLUGGING INSTRUCTIONS

USE 5/16" COPPER FLASHED DOWEL PIN EXCEPT WHERE NOTED. INSTALL PINS FLUSH TO .020" BELOW SURFACE.

	HOLE NOS. 1	2	3	4	5
6V-53*	X	X		X	X
8V-53	X	X	X	X	

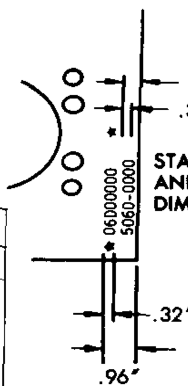
• *NO. 2 HOLE, PLUG WITH 5/16" PLAIN DOWEL PIN. NO. 5 HOLE, PLUG WITH 1/8" PIPE PLUG FLUSH TO .12" BELOW SURFACE.

FRONT

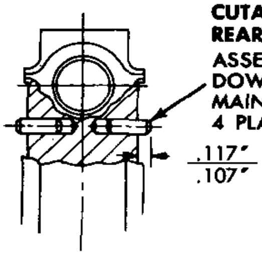


PLUG WITH .075" SPECIAL PLUG BLOCK 5149781 ONLY

NOTES
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.
• APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.



STAMP SERIAL NUMBER AND MODEL NUMBER TO DIMENSIONS SHOWN.



CUTAWAY SECTION OF REAR MAIN BEARING CAP

ASSEMBLE 5/16" x 1/2" DOWEL PINS IN REAR MAIN BEARING CAP. 4 PLACES

STANDARD PIPE PLUG TORQUE

PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

REV. 6-82

TROUBLESHOOTING

EXHAUST VALVE

Probable Causes

1. STICKING VALVE
2. IMPROPER VALVE SEATING
3. VALVE SEAT PITTED OR OVERHEATED
4. BENT VALVE
5. BROKEN VALVE
6. EXCESSIVE VALVE TO GUIDE CLEARANCE
7. CARBON DEPOSITS ON VALVE HEAD
8. VARNISH DEPOSITS ON VALVE STEM
9. SCORED OR SCUFFED VALVE STEM
10. ALL VALVES BENT
11. OIL RUNNING DOWN VALVE STEM

SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (ethylene glycol) in the lubricating oil. Replace a bent guide. Clean–up and reface the valve. Replace the valve, if necessary.

2. Check for excessive valve–to–guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.

3. Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder–face valve if operating conditions warrant.

4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four valve head) or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts.

5. Check for excessive valve–to–guide clearance, defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head and piston for damage. Replace damaged parts.

6. Replace a worn valve guide. Check and replace the valve, if necessary.

7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean–up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.

8. Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.

9. Check for a bent valve stem or guide, metal chips or dirt, or for lack of lubrication. Clean up the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem.

10. Check for a gear train failure or for improper gear train timing.

11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CYLINDER BLOCK			
Block bore:			
Diameter (top)	4.5195"	4.5215"	4.5235"
Diameter (center)	4.4865"	4.4880"	4.4900"
Diameter (bottom)	4.3565"	4.3575"	4.3595"
Out–of–round		.0015"	.0020"
Taper		.0015"	.0020"
Cylinder liner counterbore:			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	
Main bearing bore:			
Inside diameter (vertical axis, In–line)	3.2510"	3.2520"	
Inside diameter (vertical axis, V–type)	3.7510"	3.7520"	
Cam and balance shaft bore (O.S. cam brg.):			
End (all engines)	2.3850"	2.3860"	
Intermediate (3–53, 4–53, 6V and 8V)	2.3750"	2.3760"	
Center (2–53)	2.3750"	2.3760"	
Center (3–53, 4–53, 6V and 8V)	2.3650"	2.3660"	
Top surface of block:			
Flatness—transverse (all)			.0030"
Flatness—longitudinal (2–53)			.0050"
Flatness—longitudinal (3–53 and 6V)			.0060"
Flatness—longitudinal (4–53 and 8V)			.0070"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0970"	.1070"	
Water holes	.1090"	.1150"	
Water holes (at ends of 6V block)	.0920"	.0980"	
Oil holes	.0920"	.0980"	
CYLINDER LINER			
Outside diameter (upper seal ring surface)	4.4850"	4.4860"	
Outside diameter (lower seal ring surface)	4.3550"	4.3560"	
Inside diameter	3.8752"	3.8767"	
Out–of–round (inside diameter)		.0020"	.0030"
Taper (inside diameter)		.0010"	.0020"
Depth of flange BELOW block	.0465"	.0500"	.0500"
Variation in depth between adjacent liners		.0020"	.0020"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
PISTONS and RINGS (TRUNK TYPE)			
Piston:			
Diameter (at skirt):			
Non–turbocharged engines	3.8699″	3.8721″	
Turbocharged engines	3.8679″	3.8701″	
Clearance—piston skirt–to–liner:			
Non–turbocharged engines	.0027″	.0068″	.0100″
Turbocharged engines	.0047″	.0088″	.0120″
Out–of–round or taper		.0005″	
Inside dia.—pin bushing	1.3775″	1.3780″	
Inside dia.—pin bushing (current turbo)	1.5025″	1.5030″	
Compression rings:			
Gap (chrome ring)	.0200″	.0460″	.0600″
Gap (cast iron ring)	.0200″	.0360″	.0600″
Clearance—ring–to–groove:			
Top (No. 1)	.0030″	.0060″	.0120″
No. 2	.0070″	.0100″	.0140″
No. 3 and 4	.0050″	.0080″	.0130″
No. 3 and 4 (21:1 ratio piston)	.0045″	.0070″	.0120″
Oil control rings:			
Gap	.0100″	.0250″	.0440″
Clearance—ring–to–groove	.0015″	.0055″	.0080″
PISTONS and RINGS (CROSSHEAD TYPE)			
Piston crown:			
Saddle–to–crown distance	2.8325″	2.8395″	
Diameter:			
Top	3.8486″	3.8516″	
Below both comp. rings	3.8636″	3.8666″	
Above/below seal ring groove	3.8666″	3.8676″	
Above/below bearing saddle	2.8350″	2.8380″	
Compression rings:			
Gap (top fire ring)	.0230″	.0380″	.0600″
Gap (No. 2 and 3)	.0200″	.0300″	.0600″
Clearance – ring–to–groove:			
Top fire ring	.0030″	.0066″	.0086″
No. 2 (rectangular sect.)	.0070″	.0100″	.0140″
No. 3 (rectangular sect.)	.0050″	.0080″	.0130″
Piston skirt:			
Diameter	3.8695″	3.8717″	
Clearance – skirt–to–liner	.0035″	.0072″	.0110″
Seal ring bore	.3700″	.3704″	.3706″
Piston pin bore	1.3775″	1.3785″	1.3790″
Oil control rings:			
Gap (two rings – lower groove)	.0100″	.0250″	.0440″
Gap (one ring – upper groove)	.0070″	.0170″	.0370″
Clearance (two rings – lower groove)	.0015″	.0055″	.0080″
Clearance (one ring – lower groove)	.0005″	.0040″	.0065″

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
PISTON PINS (TRUNK TYPE)			
Diameter (non–turbo and former turbo)	1.3746″	1.3750″	
Diameter (current turbo)	1.4996″	1.5000″	
Clearance—pin–to–piston bushing	.0025″	.0034″	.0100″
Clearance—pin–to–conn. rod bushing	.0010″	.0019″	.0100″
PISTON PINS (CROSS–HEAD TYPE)			
Length	3.2250″	3.2450″	
Diameter	1.3746″	1.3750″	1.3730″
Slipper bearing (bushing):			
Thickness*	.0870″	.0880″	.0860″
Clearance (bushing edge–groove in piston)	.0005″	.0105″	.0120″
CONNECTING ROD			
Length—center–to–center	8.7990″	8.8010″	
Inside diameter (upper bushing)	1.3760″	1.3765″	
Normal side clearance (In–line)	.0030″	.0120″	
Normal side clearance (V–type)	.0020″	.0160″	
CRANKSHAFT			
Journal diameter:			
Main bearing (In–line)	2.9990″	3.0000″	
• Main bearing (V–Type)	3.4985″	3.5002″	
Conn. rod bearing (In–line)	2.4990″	2.5000″	
• Conn. rod bearing (V–Type)	2.7485″	2.7502″	
Outboard bearing (8V–53)		2.8770″	2.8780″
Journal out–of–round		.00025″	.0030″
Journal taper		.0005″	.0030″
#Runout on journals—total indicator reading:			
2–53, 3–53 and 4–53 engine		.0020″	
#Runout at No. 2 and No. 4 journals (8V)		.0020″	
#Runout at No. 3 journal (8V)		.0040″	
#Runout on outboard journal (8V)		.0010″	
Thrust washer thickness	.1190″	.1220″	
End play (end thrust clearance)	.0040″	.0160″	.0180″

* Center land is .0002″ – .0008″ thinner than adjacent lands.

Runout tolerance given for guidance when regrinding crankshaft. Crankshaft for 2–53 supported on No. 1 and No. 3 journals; runout measured at No. 2 journal. Crankshaft for 3–53 supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 4–53 supported on No. 1 and No. 5 journals; runout measured at No. 2, 3 and 4 journals. Crankshaft for 6V supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 8V supported on No. 1 and No. 5 journals; runout measured at No. 2, 3, 4 and outboard journals. When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003″ total indicator reading. When in the same direction, the difference must not exceed .003″ total indicator reading. When high spots of runout on adjacent journals are at right angles to each other, the sum must not exceed .004″ total indicator reading, or .002″ on each journal.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CONNECTING ROD BEARING			
Inside diameter (vertical axis, In–line)	2.5015″	2.5035″	
Inside diameter (vertical axis, V–type)	2.7511″	2.7531″	
Bearing–to–journal clearance (In–line)	.0015″	.0045″	.0060″
Bearing–to–journal clearance (V–type)	.0011″	.0041″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1247″	.1252″	.1230″
MAIN BEARINGS			
Inside diameter (vertical axis, In–line)	3.0020″	3.0030″	
Inside diameter (vertical axis, V–type)	3.5030″	3.5040″	
Bearing–to–journal clearance	.0010″	.0040″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1240″	.1245″	.1230″
OUTBOARD BEARING			
Clearance—bearing–to–crankshaft (8V)	.0035″	.0071″	.0080″
CAMSHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Runout at center bearing (mounted end brg.)		.0020″	
Thrust washer thickness	.2080″	.2100″	
BALANCE SHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Thrust washer thickness	.2080″	.2100″	
CAMSHAFT and BALANCE SHAFT BEARINGS			
Inside diameter	2.1870″	2.1880″	
Clearance—bearing–to–shaft	.0035″	.0070″	.0080″
CAMSHAFT and BALANCE SHAFT GEARS			
Backlash	.0005″	.0050″	.0070″
IDLER GEAR (IN–LINE and 6V ENGINES)			
Backlash	.0005″	.0050″	.0070″
Bearing inside diameter	2.1860″	2.1870″	
Clearance—bearing–to–hub	.0025″	.0045″	.0070″
End play	.0060″	.0130″	.0170″
Hub outside diameter	2.1825″	2.1835″	
Thrust washer thickness	.1180″	.1200″	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CRANKSHAFT TIMING GEAR			
Backlash	.0005″	.0050″	:0070″
Inside diameter (97 tooth gear)	4.0580″	4.0590″	
Inside diameter (111 tooth gear)	4.0575″	4.0585″	
Outside diameter (crankshaft)	4.0600″	4.0610″	
BLOWER DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Thrust washer thickness (4–53 and 6V)	.0930″	.1030″	
Thrust washer thickness (8V)	.1190″	.1210″	
End play (blower drive gear shaft)	.0040″	.0120″	
GOVERNOR DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
FUEL PUMP DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Bearing (inside diameter)	1.1220″	1.1230″	
Clearance – Bearing–to–hub	.0020″	.0035″	
End play	.0050″	.0180″	.0220″
Hub (outside diameter)	1.1200″	1.1205″	
Thrust washer thickness	.1580″	.1600″	
CYLINDER HEAD			
Cam follower bore (current)	1.0626″	1.0636″	
Cam follower bore (former)	1.0620″	1.0630″	
Exhaust valve insert counterbore:			
Diameter (2–valve head)	1.4390″	1.4400″	
Diameter (4–valve head)	1.1590″	1.1600″	
EXHAUST VALVE SEAT INSERTS			
Outside diameter (2–valve)	1.4405″	1.4415″	
Outside diameter (4–valve)	1.1605″	1.1615″	
Seat width	.0468″	.0781″	.0781″
Valve seat runout		.0020″	.0020″
EXHAUST VALVES			
Stem diameter (2–valve)	.3100″	.3105″	
Stem diameter (current 4–valve)	.2480″	.2488″	
Stem diameter (former 4–valve)	.2475″	.2485″	
Valve head–to–cylinder head:			
2–valve head	.002″ protr.	.032″ recess.	.037″ recess.
Current 4–valve head	flush	.024″ recess.	.039″ recess.
Former 4–valve head	.006″ protr.	.018″ recess.	.033″ recess.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
VALVE GUIDES			
Distance below top of head (2–valve)	.0100″	.0400″	
Distance below top of head (4–valve)	.1500″	.1800″	
Diameter—inside (2–valve)	.3125″	.3135″	
Diameter—inside (4–valve)	.2505″	.2515″	
Clearance—valve–to–guide (2–valve)	.0020″	.0040″	.0060″
Clearance—valve–to–guide (current 4–valve)	.0017″	.0035″	.0050″
Clearance—valve–to–guide (former 4–valve)	.0020″	.0040″	.0050″
ROCKER ARMS and SHAFTS			
Diameter—rocker shaft	.8735″	.8740″	
Diameter—inside (rocker arm bushing)	.8750″	.8760″	
Diameter—inside (valve rocker arm bore)	.8753″	.8763″	
Clearance—shaft–to–injector rocker bushing	.0010″	.0025″	.0040″
Clearance—shaft–to–valve rocker bore	.0013″	.0028″	.0040″
CAM FOLLOWERS			
Diameter	1.0600″	1.0610″	
Clearance—follower–to–current head	.0016″	.0036″	.0060″
Clearance—follower–to–former head	.0010″	.0030″	.0060″
Rollers and pins:			
Clearance—pin–to–bushing	.0013″	.0021″	.010″ Horiz.
Side clearance—roller–to–follower	.0150″	.0230″	.0230″

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE (N·m)	NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE (N·m)
1/8	10–12	14–16	3/4	33–37	45–50
1/4	14–16	19–22	1	75–85	102–115
3/8	18–22	24–30	1-1/4	95–105	129–143
1/2	23–27	31–37	1-1/2	110–130	150–177

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	(N·m)	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	(N·m)
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255–M	1	No. 6 thru 1 1/2	60,000
None	GM 260–M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280–M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275–M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290–M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300–M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455–M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

 May, 1990

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb-ft)	(lb-in)	(N·m)
Cam follower guide bolts	1/4–20	12–15		16–20
Idler gear bearing retaining bolts (8V)	1/4–20	12–15		16–20
Injector control shaft bracket bolts	1/4–28	10–12		14–16
Governor to flywheel housing bolts	5/16–18	10–12		14–16
Idler gear hub and spacer bolts	5/16–18	19–23		26–31
Oil pan bolts	5/16–18	10–20		14–27
Connecting rod nuts (6V engine – former)	5/16–24	24–28		33–38
Air box cover bolts (6V – 1/4″ thick clamp)	3/8–16	8–10		11–14
Air box cover bolts (except 1/4″ clamp)	3/8–16	12–15		16–20
Flywheel housing bolts	3/8–16	25–30		34–41
Idler gear hub and spacer bolts	3/8–16	40–45		54–61
Injector clamp bolts	3/8–16	20–25		27–34
Valve rocker cover bolts (cast cover)	3/8–16	8–13		11–18
Connecting rod nuts	3/8–24	40–45		54–61
Flywheel housing bolts	3/8–24	25–30		34–41
Fuel connector (for flared end fuel pipe)	3/8–24	20–28		27–38
● Fuel connector (for O-ring sealed fuel pipe)	3/8–24	37		50
● Fuel pipe nuts (uncoated)	3/8–24		160	18.3
● Fuel pipe nuts (Endurion ®)	3/8–24		130	14.69
● Fuel pipe nuts (Jacobs brake)	3/8–24		120	13.6
● Fuel pipe nuts (Load limiting device)	3/8–24	–	160	18.3
C/S outboard main bearing support bolt (8V)	7/16–14	75–85		102–115
Rocker arm bracket bolts	7/16–14	50–55		68–75
*Flywheel bolts (Section 1.4)	1/2–20			
*Main bearing cap bolts	9/16–12	120–130		163–177
*Flywheel bolts (8V) (Section 1.4)	9/16–18			
*Cylinder head bolts	5/8–11	170–180		231–244
Flange mounted air compressor drive shaft nut	3/4–10	#		#
Accessory drive pulley retaining nut	3/4–16	120–140		163–190
Air compressor drive pulley nut	3/4–16	80–100		108–136
Crankshaft end bolt (In-line and 6V engines)	3/4–16	290–300		393–407
C/S end bolt pulley stamped "A"	1–14	200–220		271–298
Crankshaft end bolt (8V)	1–14	290–310		393–421
Crankshaft and balance shaft nut	1-1/8–18	300–325		407–441

* Lubricate at assembly with International Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).

\# 100 lb-ft (136 N·m) plus increase torque to line up cotter pin.

SERVICE TOOLS

TOOL NAME	TOOL NO.
CYLINDER BLOCK	
Bore gage	J 5347-B
Cylinder bore plug set	J 34697
Deck checker (measure crankshaft centerline-to-fire deck)	PT 5075-B
Dial bore gage master setting fixture	J 23059-01
Engine overhaul stand	J 29109
• Adaptor plate (In-line)	J 7622-01
• Adaptor plate (6V)	J 8683
• Adaptor plate (8V)	J 21966
• Adaptor plate (2, 3, 4-53, 6V-53, 8V-53))	J 33850
Pipe plug remover and installer (1/8' dia.)	J 34650
Sled gage	J 22273-01
• Loctite "chisel" gasket remover	PT 7275
CYLINDER HEAD	
• Cam follower service fixture adaptor	J 33421-22
• Load cell, cam follower roller fixture	J 33421-25
Cylinder head guide studs (set of 2)	J 9665
Cylinder head lifting	J 22062-01
Engine barring tool	J 22582
Injector body brush	J 8152
piston ring gap feeler gage set	J 3172
Push rod remover (set of 3)	J 3092-01
Socket	J 8932-01
Spring tester	J 22738-02
Valve guide cleaner (2-valve head)	J 5437
Valve guide cleaner (4-valve head)	J 7793
Valve guide installer (2-valve head)	J 7560
Valve guide installer (4-valve head)	J 24519
Valve guide oil seal installer (4-valve head)	J 29579
Valve guide remover (2-valve head)	J 6569
Valve guide remover (4-valve head)	J 7775
• Valve seat grinder, model V.I.P. (consists of dash (-) items)	J 7040-A
- Valve seat dial gage	J 8165-2
- Valve seat grinder	J 8165-1A
Valve seat grinder adaptor kit (2-valve head)	J 7924-02
Valve seat grinder adaptor kit (4-valve head)	J 7792-01
Valve seat insert installer (2-valve head)	J 6976
Valve seat insert installer (4-valve head)	J 7790
Valve seat insert remover	J 23479-15
Valve seat insert remover collet (2-valve head))	J 23479-7
Valve seat insert remover collet (4-valve head))	J 23479-8
Valve spring checking gage	J 25076-B
Valve spring compressor (2 or 4-valve head)	J 7455
CRANKSHAFT	
Front oil seal installer	J 22153
Front oil seal sleeve installer (In-line 6V)	J 22524
Pulley installer	J 7773

TOOL NAME	TOOL NO.
Pulley remover	J 5356
Rear oil seal expander (8V)	J 22425–A
Rear oil seal (O.S.) expander	J 21278–01
Rear Oil seal sleeve installer	J 21277
Handle	J 3154–1
Rear oil seal sleeve installer (8V)	J 4194–01
Timing gear installer	J 7557
Timing gear remover	J 4871
Micrometer ball attachment	J 4757
Oil seal expander	J 9769
Oil seal expander (In–line and 6V)	J 7454
Oil seal installer	J 9479
Oil seal installer	J 9727–A
Handle	J 3154–1
Oil seal installer	J 9783
Puller	J 24420–A
FLYWHEEL	
Flywheel lifting fixture	J 25026
Flywheel lifting tool	J 6361–01
Removing and replacer set	J 3154–04
Slide hammer puller set	J 5901–01
FLYWHEEL HOUSING	
Oil seal expander (8V)	J 22425–A
Oil seal expander (O.S. seal)	J 21278–01
Oil seal expander (Std. size seal)	J 9769
Dial indicator	J 8001–3
Post	J 9748
Sleeve	J 8001–2
Aligning studs (set of 2)	J 7540
Concentricity gage	J 9737–C
PISTON, CONNECTING ROD and CYLINDER LINER	
Bore gage	J 5347–B
Connecting rod bushing reamer set	J 7608–02
Connecting rod holding	J 7632
Cylinder hone set (2 1/2″ to 5 3/4″ range)	J 5902–01
Cylinder liner remover set	J 22490
Dial bore gage master setting fixture	J 23059–01
Hold down clamp	J 21793–B
Master ring – cylinder liner	J 8385–01
Micrometer ball attachment	J 4757
Piston and connecting rod bushing installer and remover	J 7587
Piston bushing reamer set	J 4970–02
Piston bushing reaming fixture	J 5273
Piston pin alignment tool (cross–head)	J 35619
• Piston pin bushing reamer set	J 3071–B
Piston pin retainer installer	J 23762–A
Piston pin retainer installer (cross–head)	J 35572
Piston pin retainer installer (turbo trunk)	J 24107–01

TOOL NAME	TOOL NO.
Piston pin retainer leak detector (plastic)	J 23987–01
• Piston pin retainer leak detector (all metal)	J 35134
Piston ring compressor	J 6883–01
Piston ring remover and installer	J 8128
Piston to liner feeler gage set	J 5438–01
Sled gage	J 22273–01
Spray nozzle remover	J 8995
Piston pin bushing reamer set	J 3071–B
CAMSHAFT	
Bar type puller	J 24420–A
Bearing remover/installer set	J 7593–03
Camshaft cup plug installer	J 24094
Camshaft oil seal installer	J 21899
Slide hammer	J 6471–02
Spring scale	J 8129
Upper front cover seal installer	J 9790

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

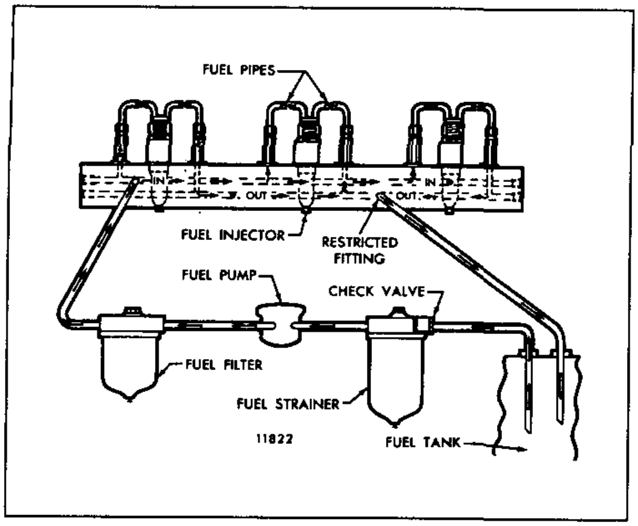


Fig. 1 – Typical Fuel System for In-Line Engines

The fuel system (Figs. 1 and 2) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines. Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. On V–type engines, the restricted fitting is located at the rear of the left–bank cylinder head. Refer to Section 13.2 for the size fitting required.

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back when the engine is shut down.

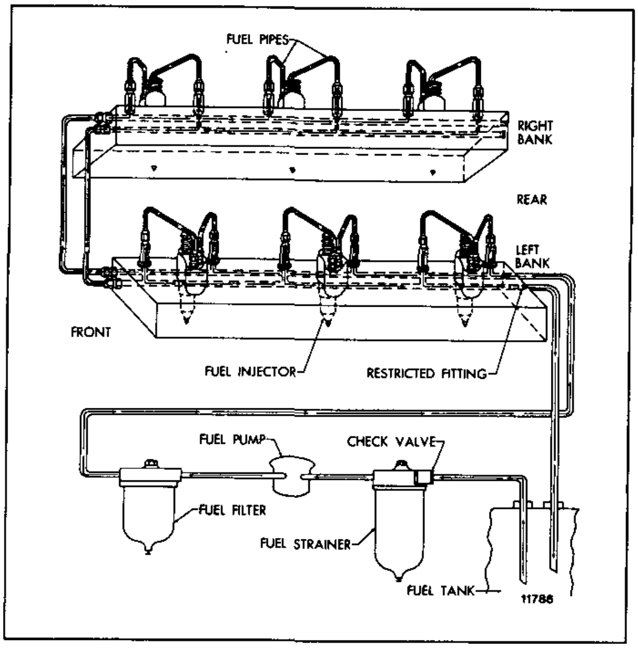


Fig. 2 – Fuel System for 6V–53 Engines

 May, 1990

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)

CROWN VALVE

The fuel injector (Fig. 1) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air–fuel mixing or vaporizing devices are required.

The fuel injector performs four functions (Times – Atomizes – Meters – Pressurizes):

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

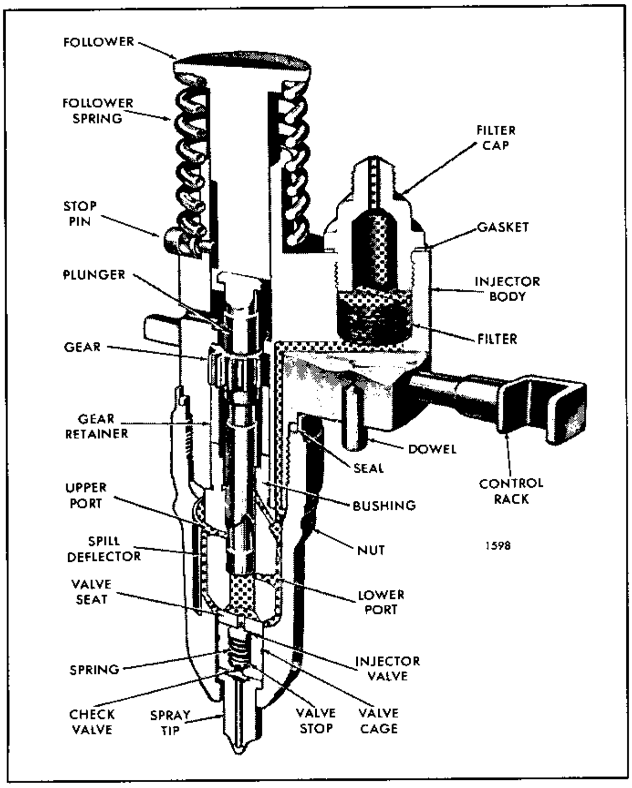


Fig. 1 – Fuel Injector Assembly

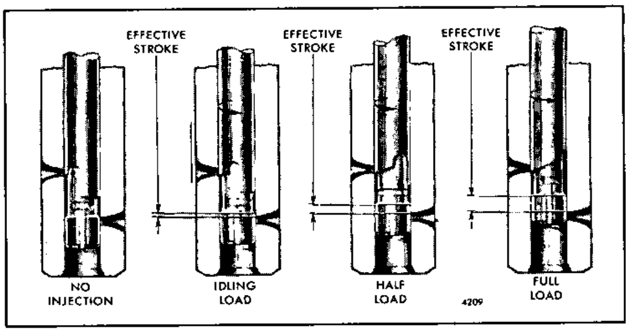


Fig. 2 – Fuel Metering from No Load to Full Load

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. (Fig. 2) illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

(Fig. 3) illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

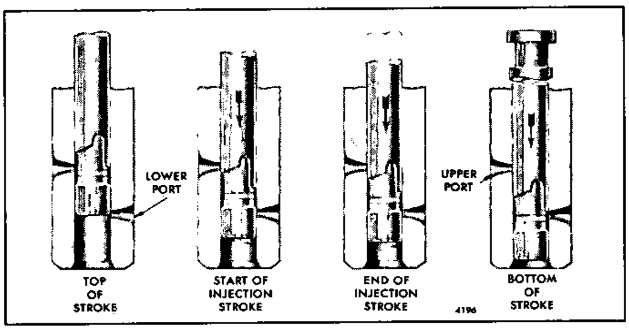


Fig. 3 – Phases of Injector Operation Through Vertical Travel of Plunger

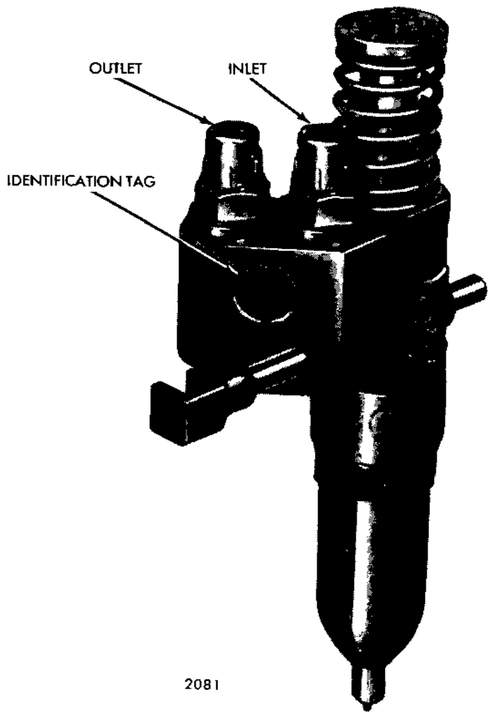


Fig. 4 – Injector Identification

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 4).

Each injector control rack (Fig. 1) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting or fine tuning of all of the injector racks.

The injectors used in engines with a four valve cylinder head require an offset injector body due to the restricted area around the exhaust valve mechanism. A narrower injector clamp is required with the offset injector body and may not be used with the standard injectors. Most offset body injectors, designated as the "S" type, incorporate a clamp seat which is machined lower on the injector body and requires the current narrower clamp (Fig. 5).

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

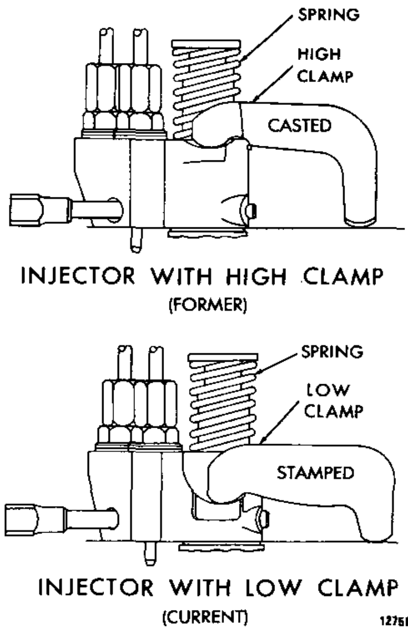


Fig. 5 – Comparison of High Clamp and Low Clamp Injectors

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the rack (Fig. 1). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel–shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through the T–drilled passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

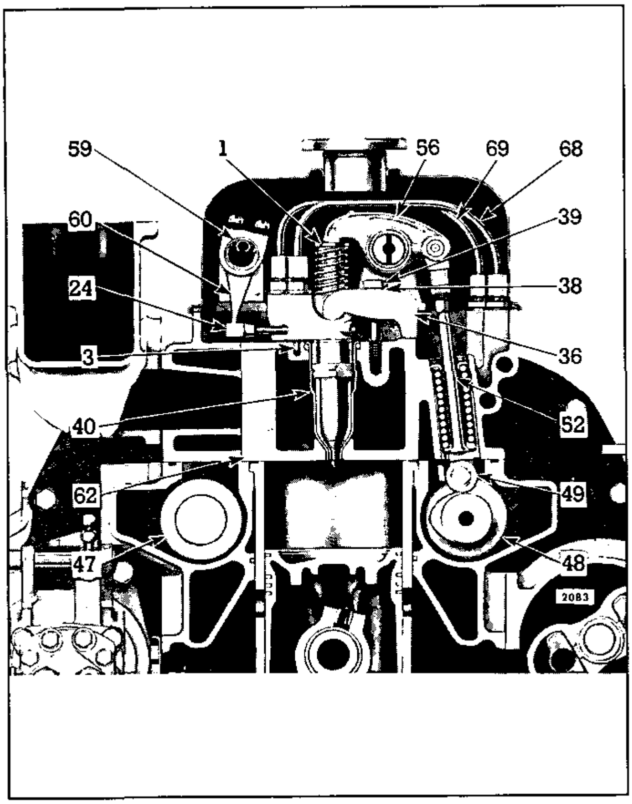


Fig. 6 – Fuel Injector Mounting

When sufficient pressure is built up, the injector valve is lifted off of its seat and the fuel is forced through small orifices in the spray tip and atomized into the combustion chamber until the lower port becomes uncovered.

A check valve, mounted in the spray tip, prevents air in the combustion chamber from entering the fuel injector through the spray holes.

At the end of the stroke the injector plunger is then returned to its *original* position by the injector follower spring. (Fig. 3) shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return stroke of the plunger, the bore of the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection cycle. At the same time, it increases or decreases the amount of fuel injected into the cylinder. (Fig. 2) shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not covered by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is covered shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this *no injection* position to *full injection* position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of atomized fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against the high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first–class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and *clean water–free fuel* are the keys to trouble–free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the door and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture–proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust–proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint–free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out

of the injector and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.

2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and overhaul of an injector.

3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:

    a. Time the injector.

    b. Position the injector control rack.

4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Section 15.3).

5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

NOTICE: Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

- DDC recommends that flared end fuel pipes not be reused.

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

NOTICE: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent damage and to prevent dirt from entering the injector. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or foreign material.

- DDC recommends that flared end fuel pipes not be reused.

3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left–hand direction of rotation because the bolt could be loosened.

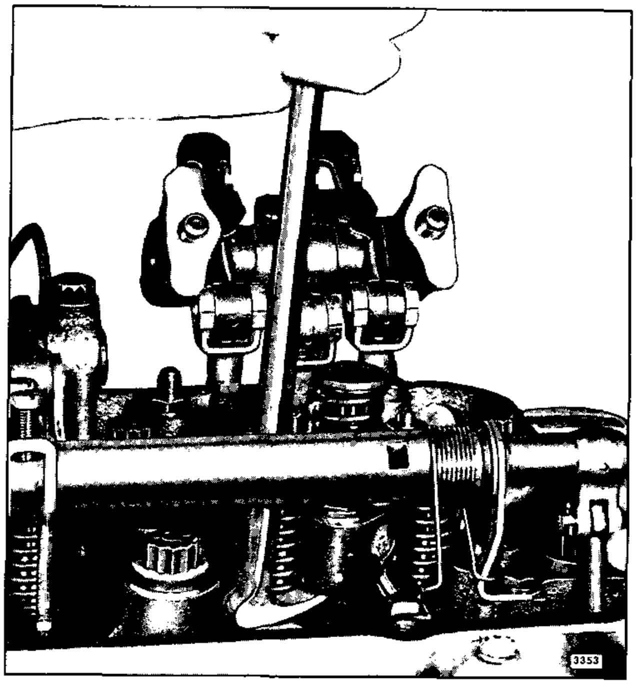


Fig. 7 – Removing Injector from Cylinder Head

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

7. Lift the injector from its seat in the cylinder head (Fig. 7).

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Fig. 8 – Checking Rack for Freeness in Tester J 29584

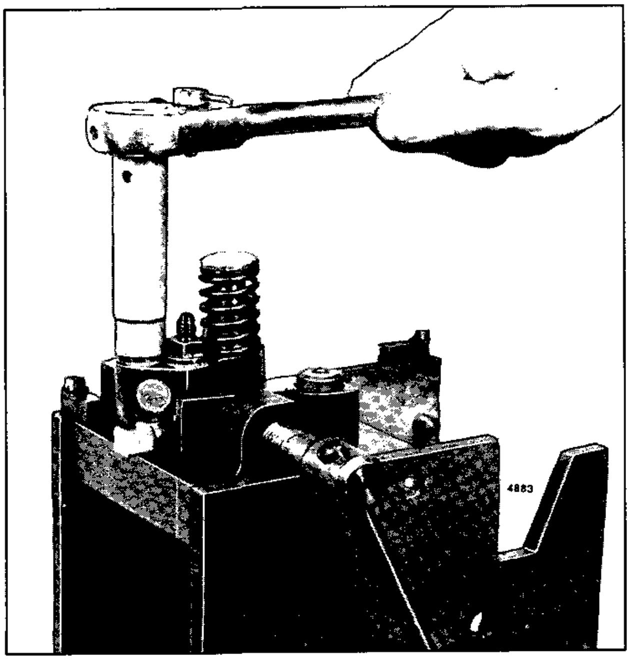


Fig. 9 – Removing Filter Cap

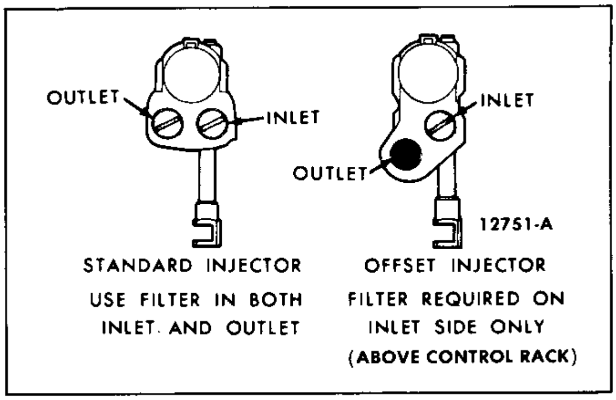


Fig. 10 – Location of Filter in Injector Body

Inspect and Test Prior to Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrostion.

   Follower spring
   Injector body
   Body nut
   Spray tip
   Injector rack
   Filter caps

2. Inspect the following parts for wear or abrasion deterioration.

   Top of the follower
   Follower spring
   Injector body
   Spray tip orifices

3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 8). If the rack falls freely the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.

4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

   If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

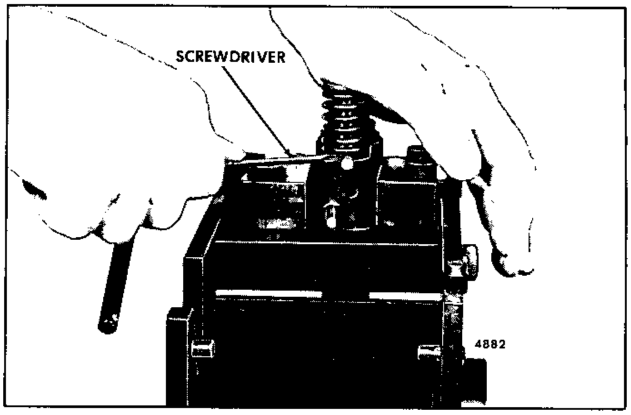


Fig. 11 – Removing Injector Follower Stop Pin

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 9) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 10).
2. Compress the follower spring (Fig. 11). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.
3. Refer to (Fig. 12) and remove the plunger follower, plunger and spring as an assembly.
4. Using socket J 4983–01, loosen the nut on the injector body (Fig. 13).
5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing.

   When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291–02 (Fig. 14).
6. Refer to (Fig. 15) and remove the spill deflector. Then, lift the bushing straight out of the injector body.
7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.
8. Withdraw the injector control rack from the injector body. Also, remove and discard the seal ring from the body.

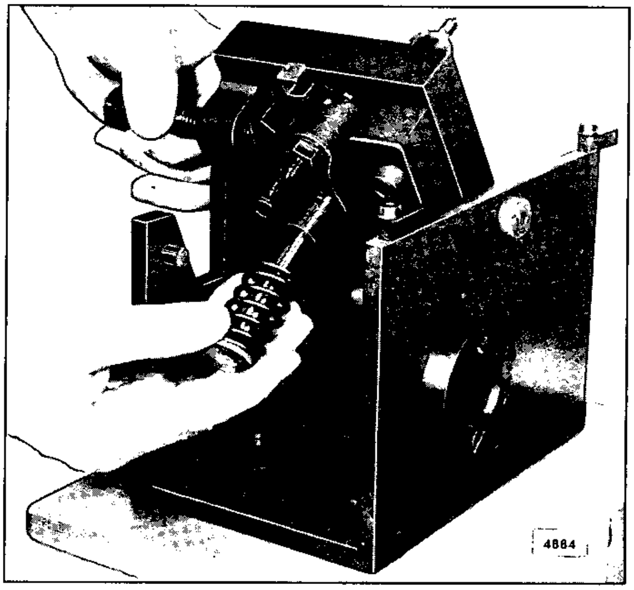


Fig. 12 – Removing or Installing Plunger Follower, Plunger and Spring

Clean Injector Parts

Since most injector problems are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with a suitable solvent and dry them with clean, filtered compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with Tool J 1243 (Fig. 16). Turn the reamer in a clockwise direction to remove the carbon deposits.

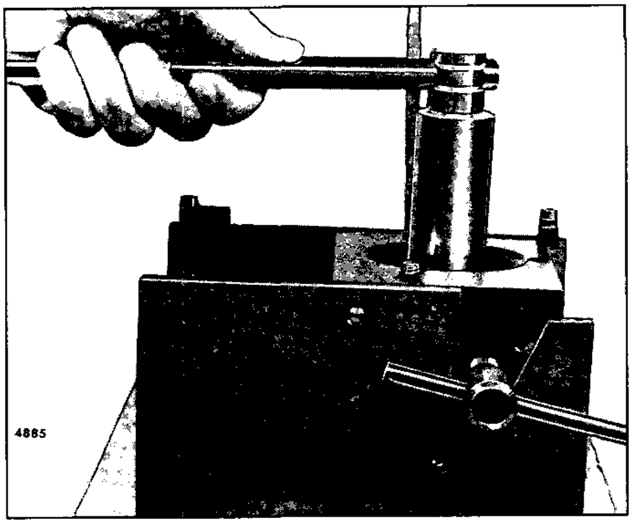


Fig. 13 – Removing Injector Nut Using Tool J 4983-01

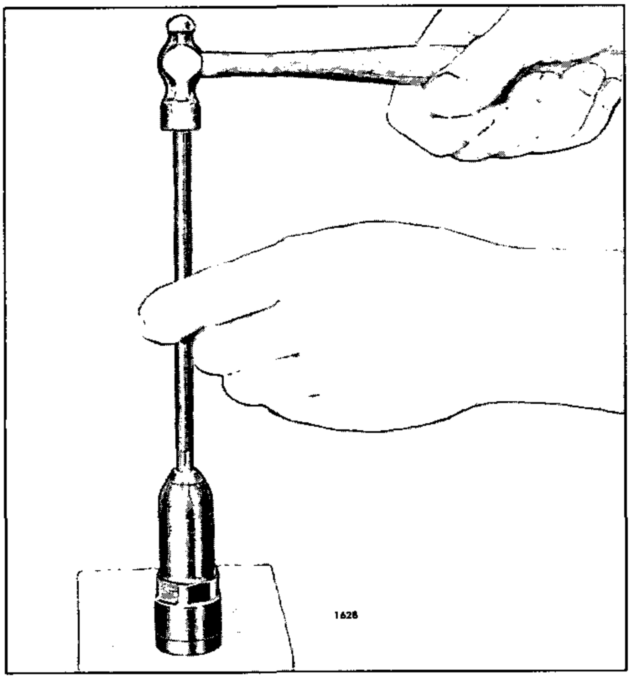


Fig. 14 – Removing Spray Tip from Injector Nut Using Tool J 1291-02

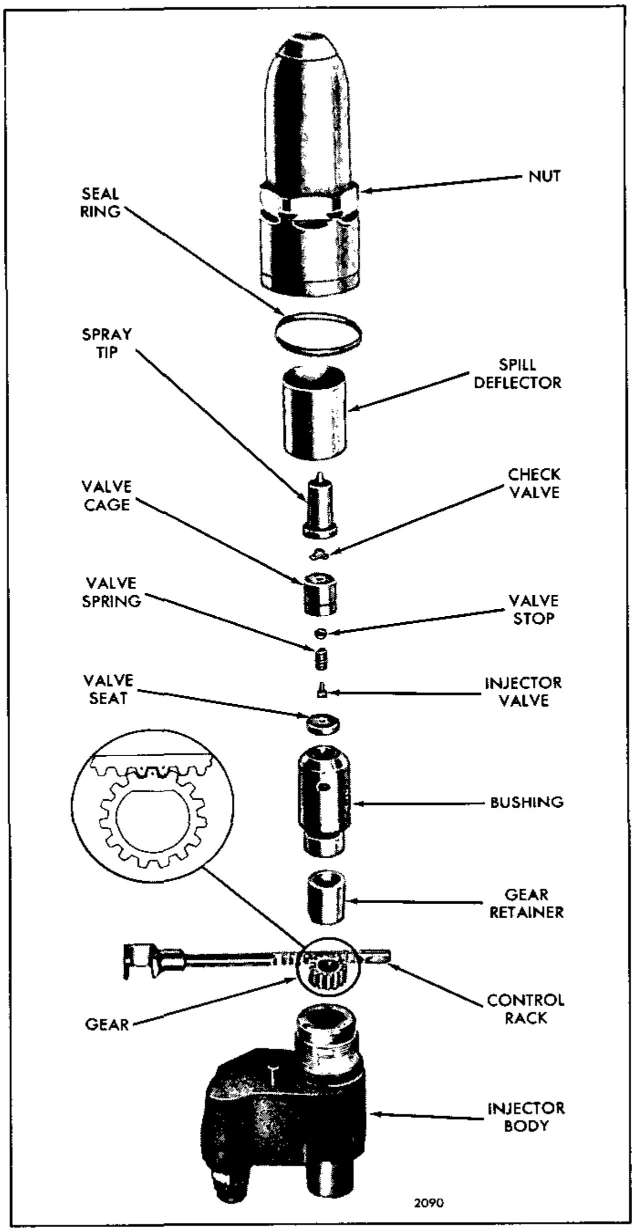


Fig. 15 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298–1, and the proper size spray tip cleaning wire. Use wire J 21459–01 to clean .005″ diameter holes and wire J–21461–01 to clean .006″ diameter holes (Fig. 17).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16″ with stone J 8170. Allow the wire to extend 1/8″ from tool J 4298–1. Ultra sonic cleaning is also an acceptable method.

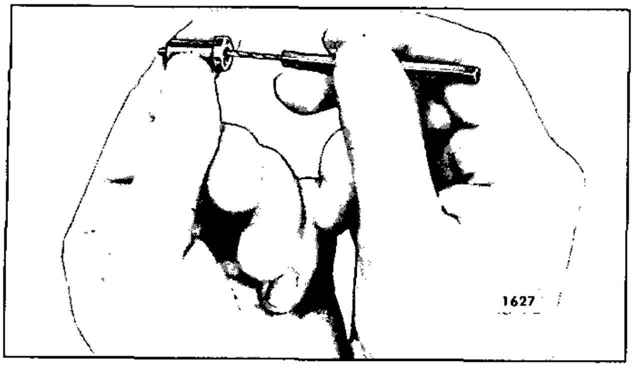


Fig. 16 – Cleaning Injector Spray Tip Using Tool J 1243

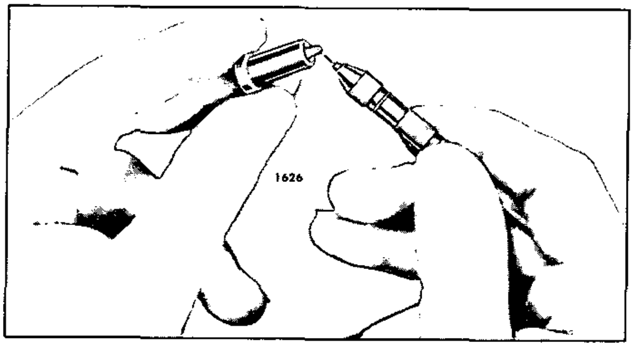


Fig. 17 – Cleaning Spray Tip Orifices Using Tool J 4298-1

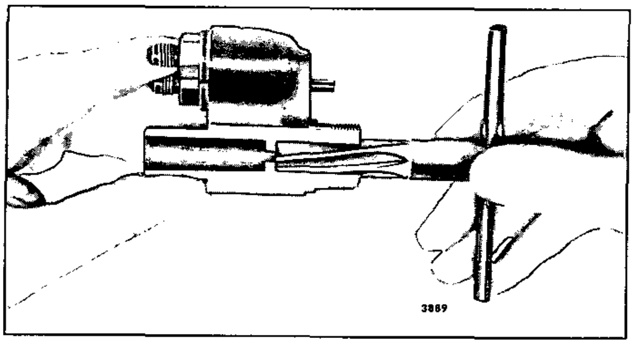


Fig. 18 – Cleaning Injector Body Ring with Tool J 21089

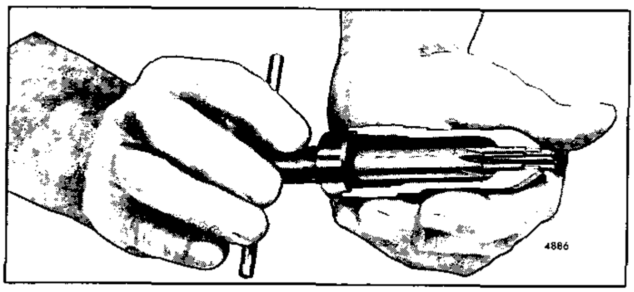


Fig. 19 – Cleaning Injector Nut Spray Tip Seat Using Tool J 4986–01

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kpa) air pressure.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully, insert reamer (J 21089) into the ring bore of the injector body (Fig. 18). Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then, wash the injector body in clean solvent and dry it with compressed air.

Carefully, insert reamer J 4986–01 in the injector nut (Fig. 19). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the seat for reamer contact over the entire surface. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the seat.

Wash the injector nut in clean solvent and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. *Keep the plunger and bushing together as they are mated parts.*

After washing, submerge the parts in a clean receptacle containing clean test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual and Dimensional)

NOTICE: Injector components manufactured after January 1, 1988 may or may not be blued, at the discretion of the manufacturer. Bluing has no effect on a part's performance or service life.

1. Follower:

   Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002″ (Fig. 20).

   Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002″ wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 29196.

   The current injector follower spring (.142″ diameter wire) has a free length of approximately 1.504″ and should be replaced when a load of less than 70 lbs. will compress it to 1.028″. The former spring wire was .120″ diameter.

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.142″ diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

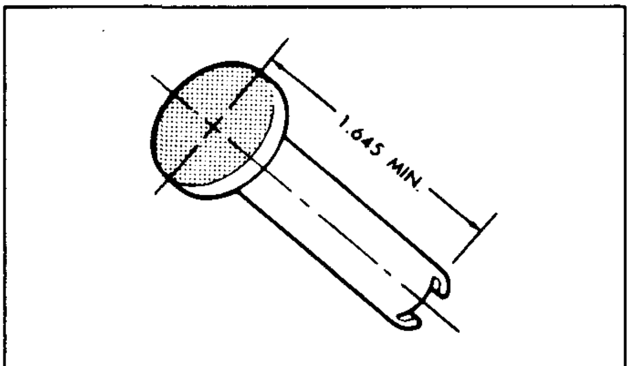


Fig. 20 – Injector Follower

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces fordamage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Caps:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125″ to .3145″. A .250″ inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer:

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

7 & 8 Plunger Bushing Assembly

Effective with injectors manufactured in October, 1985, the P & B (plunger and bushing) assemblies of all fuel injectors have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation.

Revised P & B assemblies are identified with a black locating pin at the top of the bushings. Injector assemblies containing revised P & B's are date stamped on the body with a "10–85" (for October, 1985) or later build date. Revised P & B assemblies are physically interchangeable with early P & B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.

NOTICE: Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise–versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 21).

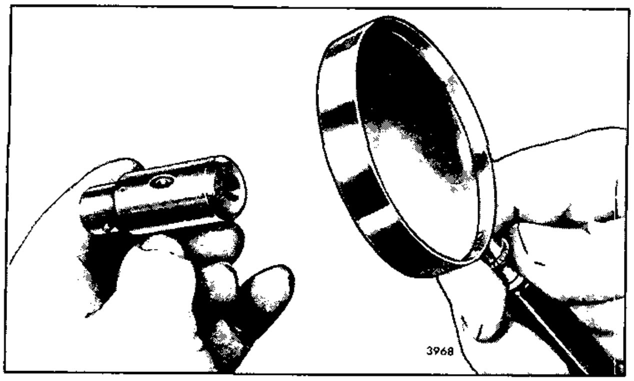


Fig. 21 – Examining Sealing Surface with a Magnifying Glass

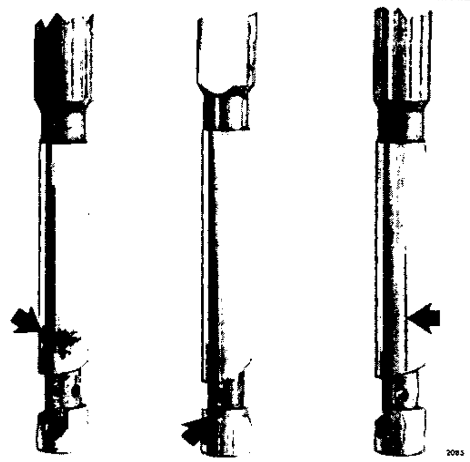


Fig. 22 – Unusable Injector Plungers

Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Fig. 22).

9. Valve Seat:

   Inspect for cracks, corrosion or varnish and scratches on the lapped sealing surfaces.

10. Check Valve Cage:

    Inspect the check valve cage for cracks, flatness and scratches on the lapped surfaces or for corrosion, varnish and wear.

11. Injector Valve (Crown):

    Inspect the injector valve for scratches on the lapped surface.

12. Valve Spring:

    Check the injector valve spring for wear on the coil ends, broken coil ends and notches under the coil ends. Then, check for corrosion, nicks and cavitation erosion on the inside at approximately 1–1/2 coils from the end.

13. Valve Stop:

    Inspect the valve stop for rust, burrs and varnish.

14. Check Valve:

    Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.

15. Spray Tip:

    Check for cracks, enlarged spray holes and oxide scale on the spray hole end. Then, check the nut–to–tip sealing surface and the lapped sealing surface for scratches. Do not reuse if there is scale, cracks or enlarged spray holes.

16. Spill Deflector:

    Inspect both ends of the spill deflector for sharp edges or burrs.

17. Nut:

    Check the nut for damaged threads, the condition of the seal ring seating area, the condition of spray tip seating area and the spray tip hole for being corroded irregularly.

18. Part Thickness:

    Check the minimum thickness of the parts (see Table 1).

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163"–.165"
Check Valve	.022"
Valve Spring Cage	.602"

TABLE 1 – MINIMUM THICKNESS (Used Parts)

Recondition Injector

If any of the injector parts listed below cannot be reconditioned satisfactorily, use new parts. All parts must be cleaned to be free of rust, varnish and carbon before reuse.

1. Follower:

   - Resurface or replace if worn beyond dimensional limits.

2. Follower spring:

   - Reuse unless damaged, worn or won't meet test specifications.

3. Injector Body:
   - Lap bushing seat.
   - Reblue.
   - Repair damaged threads.
   - Replace body if the clamp radius is badly worn or if the threads are less than 90% good.
4. Filter Caps:
   - Recondition tapered seat.
   - Clean and deburr hole.
   - Reblue.
   - Replace if the threads or sealing surfaces are damaged.
5. Control Rack:
   - Deburr teeth – check for straightness.
   - Replace if bent or the teeth show significant wear.
6. Gear and Gear Retainer
   - Deburr.
   - Replace if cracked or significantly worn.
7. Bushing:
   - Replace if scored, cracked or if residue cannot be removed.
   - Lap the check valve seat (sealing) surface.
8. Plunger:
   - Clean – remove varnish.
   - Replace if scored, chipped or scratched.
9. Valve Seat:
   - Lap both flat (sealing) surfaces.
   - Lap edge of hole (Fig. 23).
   - Replace.
10. Check Valve Cage:
    - Lap both flat sealin surfaces.
    - Replace if cracked of too thin (see Table 1).
11. Injector Valve (Crown)
    - Replace.
12. Valve Spring:
    - Replace. Do not reuse unless there is absolutely no wear or damage.
13. Valve Stop
    - Remove rust, burrs or varnish.
    - Replace.
14. Check Valve:
    - Lap both flat (sealing) surfaces.
    - Replace if scratched, cracked of badly worn.

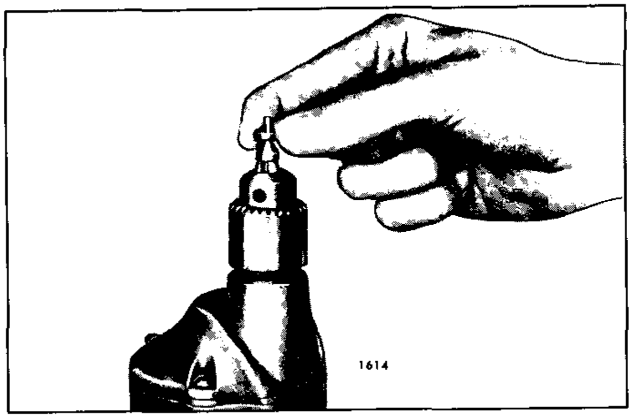


Fig. 23 – Lapping Edge of Hole in Valve Seat Using Tool J 7174

15. Spray Tip:
    - Lap flat sealing surface.
    - Replace if beyond flow limits i.e., eroded spray holes.
16. Spill Deflector:
    - Remove burrs.
    - Reuse if the ends are smooth and even and the deflector is not cracked.
17. Nut:
    - Remove carbon from the seat.
    - Reblue.
    - Replace *if the threads are damaged more than 10%* or if the small I.D. is badly eroded.

Normally, new service replacement parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solidified preservative. If the new parts become nicked or burred during handling, then lapping will be necessary to provide adequate sealing between the flat parts.

The sealing surface of current parts are precision lapped by a new process which leaves the surface with a dull satin–like finish; the lapped surface on former spray tips was bright and shiny. It is not recommended or necessary to lap the surface of a new current spray tip.

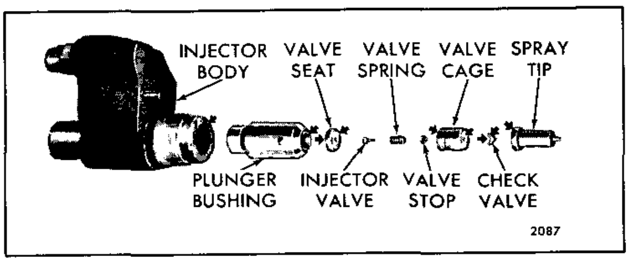


Fig. 24 – Sealing Surfaces Which May Require Lapping

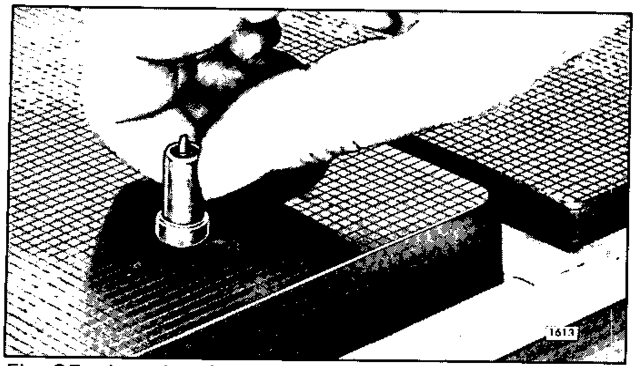


Fig. 25 – Lapping Spray Tip on Lapping Blocks J 22090

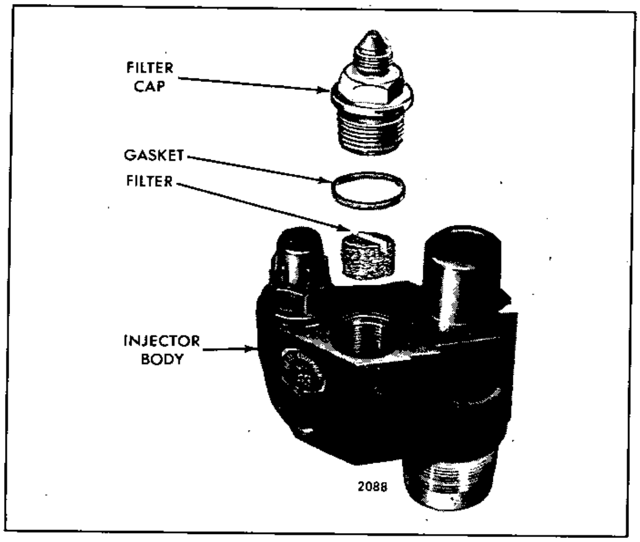


Fig. 26 – Details of Injector Filters and Caps and Their Relative Location

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in (Fig. 24) as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3. Place the part to be lapped flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. *Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.*

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*

5. When the part is flat, wash it in clean solvent and dry it with compressed air.

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again, wash the part in cleaning solvent and dry it with compressed air.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives the "mirror" finish required for easy inspection.

8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Injector

1. Secure the body in vise J 22396–1.

● 2. Insert new filter(s) in the top of the body (Fig. 26). The current production service filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The former service filter (fiberglass–filled nylon cone) was installed with the pointed (cone) end up.

   Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).

● 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps (Fig. 28). Using a 9/16″ deep socket and a torque wrench tighten the filter caps as follows:

   Non–blued cap on non–blued body . . . . 62 lb–ft (84 N·m) torque

   Blued cap on blued body . . . . 70 lb–ft (95 N·m) torque

   Non–blued cap on blued body or blued cap on non–blued body . . . . 62 lb–ft (84 N·m) torque

4. *Install clean shipping* caps to protect the sealing surfaces and to prevent dirt from entering the injector.

5. Lubricate thread protector J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the protector over the threads of the injector body.

 May, 1990

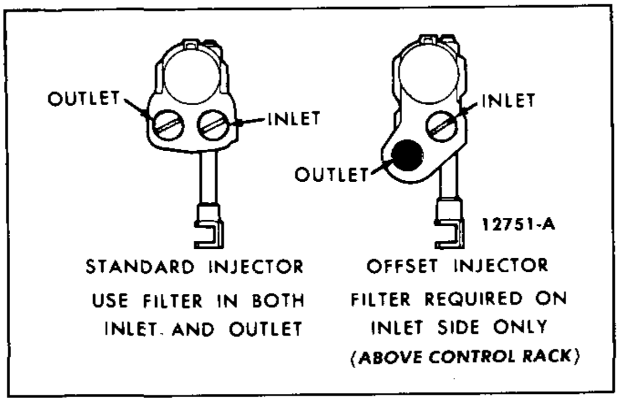


Fig. 27 – Location of Filter in Injector Body

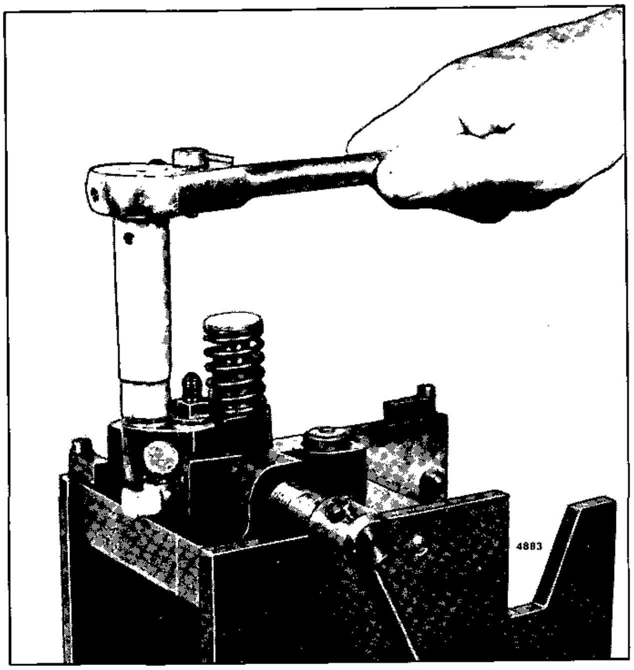


Fig. 28 – Installing Filter Cap

6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

   - A new round (in cross–section) injector nut seal ring replaced the former diamond–shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal ring is serviced.

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

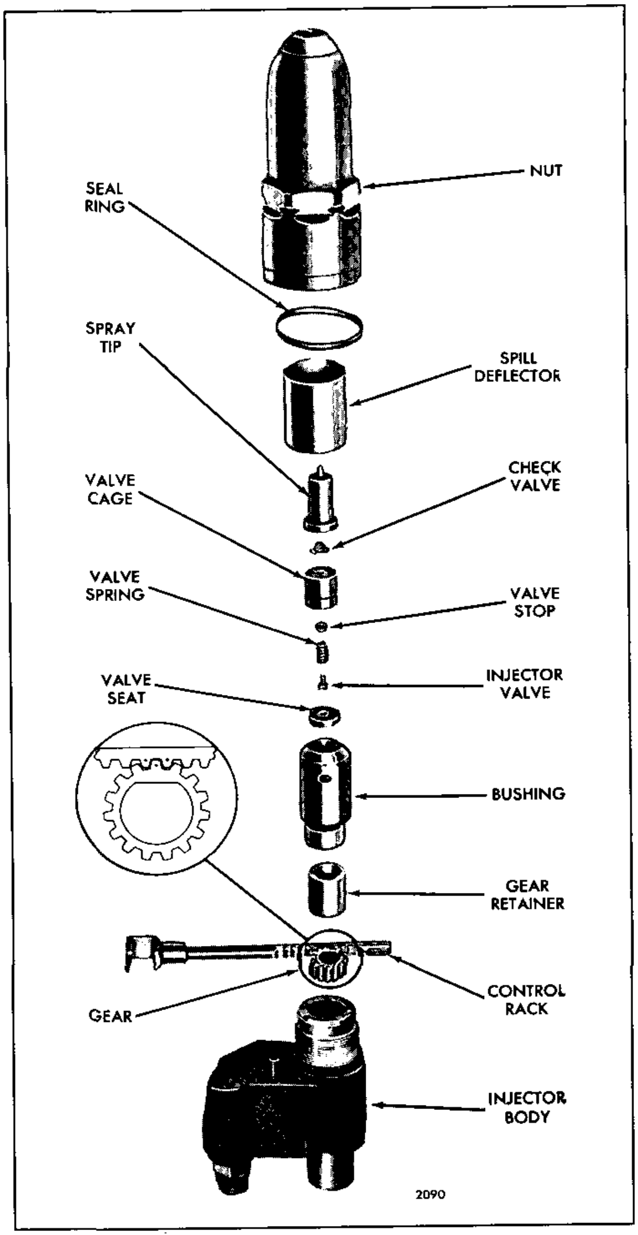


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

9. Refer to (Fig. 29) and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396–1.

14. Install the spill deflector over the barrel of the bushing.

15. Insert the valve stop, valve spring and injector valve into the valve cage.

16. Place the valve seat centrally on the top of the bushing.

17. Place the valve cage and related parts (injector valve down) on top of the valve seat.

18. Locate the check valve centrally on the cage and place the spray tip over the check valve and against the valve cage.

19. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 30). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

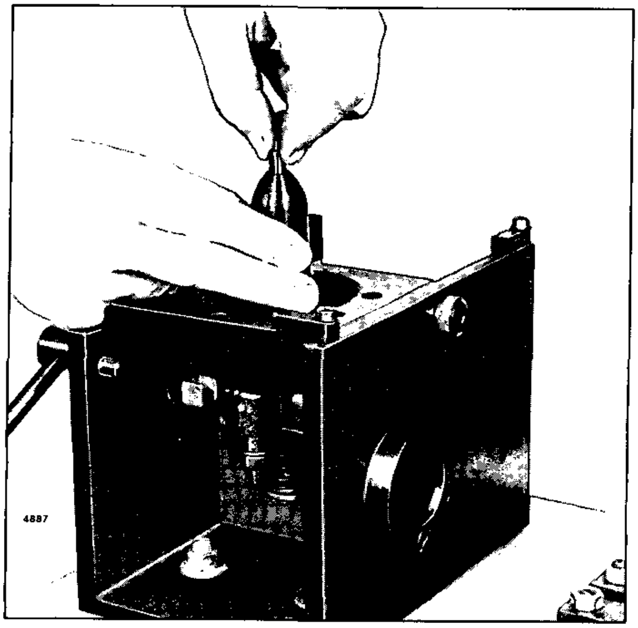


Fig. 30 – Tightening Injector Nut by Hand

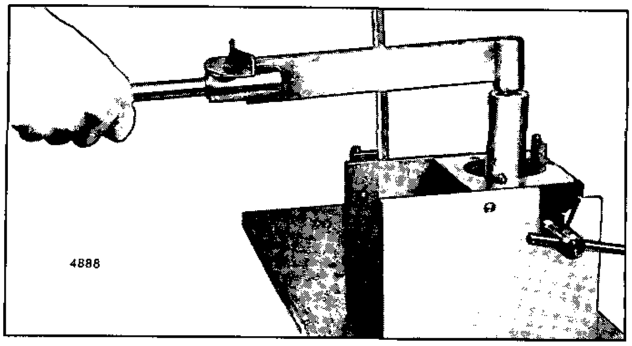


Fig. 31 – Tightening Injector Nut with Torque Wrench Using Tool J 4983–01

• 20. Use socket J 4983–01 and a torque wrench to tighten the injector nut as follows:

Non–blued nut on
non–blued body . . . . 50 lb–ft (68 N·m) torque

Blued nut on
blued body . . . . 80 lb–ft (108 N·m) torque

Non–blued nut on blued
body or blued nut on
non–blued body . . . . 65 lb–ft (88 N·m) torque

21. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

NOTICE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

22. Turn the injector over and push the rack all the way in.

23. Place the follower spring on the injector body.

24. Refer to (Fig. 32) and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.

25. Refer to (Fig. 33) and slide the head of the plunger into the follower.

26. Align the slot in the follower with the stop pin hole in the injector body.

27. Align the flat side of the plunger with the flat in the gear.

28. Insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

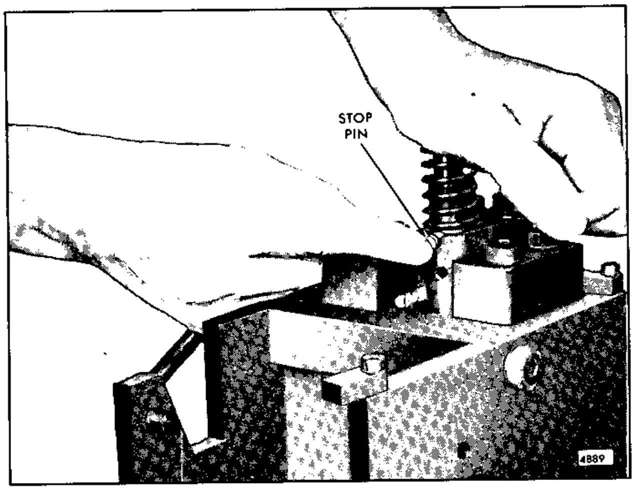


Fig. 32 – Installing Injector Follower Stop Pin

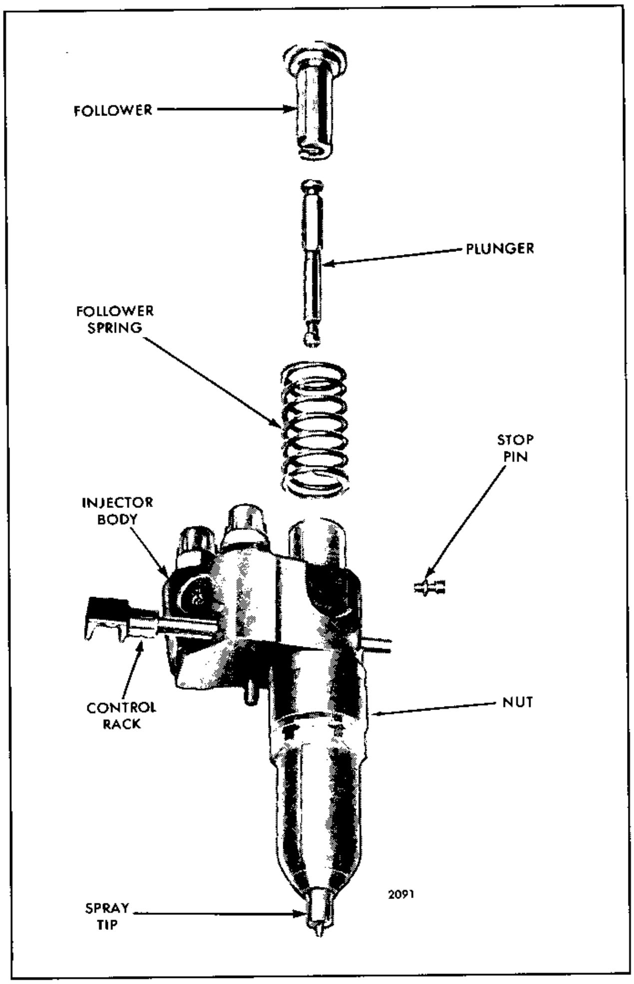


Fig. 33 – Injector Plunger, Follower and Relative Location of Parts

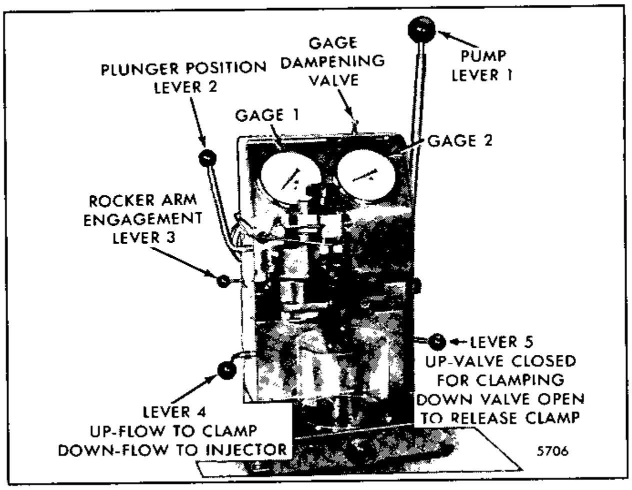


Fig. 34 – Injector in Position for Testing with Tester J 23010–A

Check Injector Output

Perform the injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

Check Atomization and Spray Pattern

This test determines spray pattern uniformity and atomization.

1. Clamp the injector properly and purge the air from the system (Fig. 34).
2. Move lever 4 down.
3. Position the injector rack in the *full–fuel* position.
4. Place pump lever 1 in the *vertical* position.
5. Move lever 3 to the *forward detent* position.
6. The injector follower should be depressed rapidly using pump lever 1 (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

Check Pressure Holding and Test for Leaks

This test determines if the body–to bushing mating surfaces in the injector are sealing properly and indicates proper plunger–to–bushing fit.

1. Clamp the injector properly in Tester J 23010–A and purge the air from the system (Fig. 34).
2. Close The Thru–Flow valve, but do not overtighten.
3. Move lever 2 to the rear, *horizontal* position.

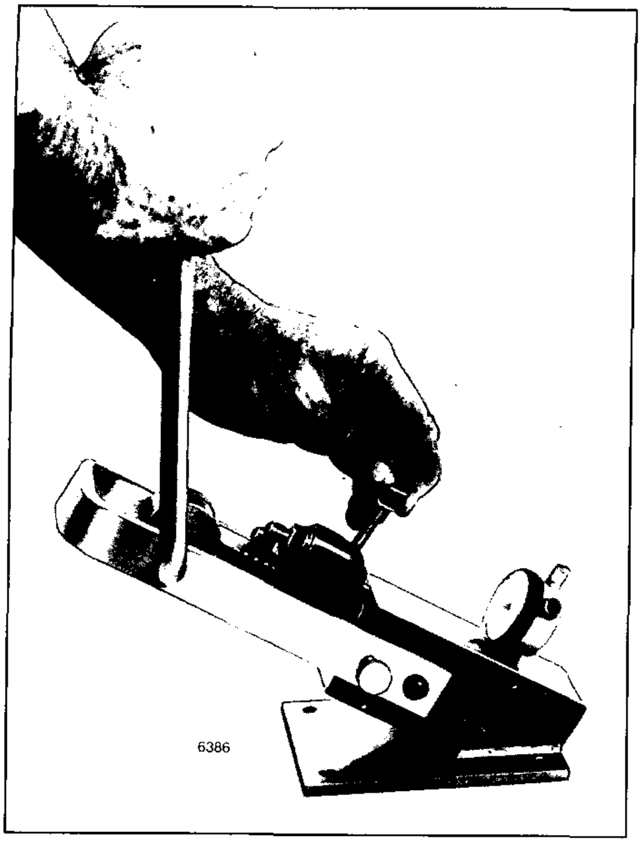


Fig. 35 - Checking Rack for Freeness in Tester J 29584

4. Operate pump lever 1 until gage 1 slowly reaches 100–200 psi (689–1378 kPa), check for injector nut seal ring leaks. Then, move lever 2 until the plunger closes both bushing parts. Operate pump lever 1 and increase the gage reading to 1500–2000 psi (10 335–13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs. Allow the plunger to go back to the *normal* position. Operate pump lever 1 and bring the pressure up to 500 psi (3445 kPa). Note the time for the pressure to drop from 450 psi to 250 psi (3100 kPa to 1723 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.

5. To unclamp the injector use the following procedure:

   a. Open the Thru–Flow valve to release the pressure in the system.

   b. Move lever 5 *down* to release the clamping pressure.

   c. Swing out the adaptor plate and remove the injector after the seals in the clamping head are free and clear of the injector filter caps.

   d. Carefully, return lever 5 to the *up (horizontal)* position.

Check Rack Freeness and Spray Tip Concentricity

Place the injector in Tester J 29584 (Fig. 35) and check rack freeness.

With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel. If the rack falls freely the injector passes the test.

If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times, if necessary. Generally, this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts or to remove dirt.

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 29584 (Fig. 35) and adjust the dial indicator to zero.
2. Rotate the injector 360° and note the total runout as indicated on the dial.
3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 55–65 lb–ft (75–88 N·m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box and Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylinderical wire brush (Section 2.1.4), to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrussion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

Not serviced. Available from Jacobs Manufacturing Company.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Insert the injector into the injector tube with the dowel in the injector body registering with the locating hole in the cylinder head.
2. Slide the rack control lever over so that it fully engages the injector rack clevis.
3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb–ft (27–34 N·m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0 – Specifications.

   NOTICE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridges are not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridges before, during and after tightening the rocker shaft bolts.

5. Install fuel pipes:

   Remove the shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

   NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

   NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 ***lb–in*** (14.69 N·m) torque, instead of the 160 ***lb–in*** (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

   Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

   NOTICE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks in Section 2.0 – Shop Notes).

   An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover.

   A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil.

   Remove and replace the leaking fuel pipes and/or connectors. Use new gasket(s) and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

6. Perform a complete engine tune–up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control levers.

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)

NEEDLE VALVE

The fuel injector (Figs. 1 and 2) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air–fuel mixing or vaporizing devices are required.

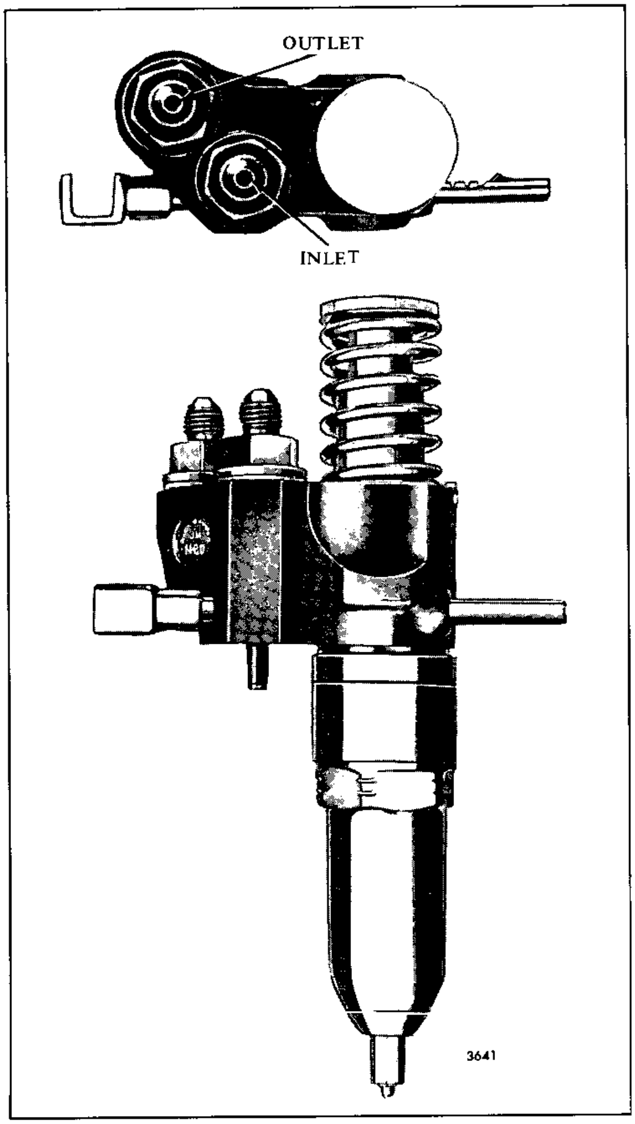


Fig. 1 – Fuel Injector Assembly

The fuel injector performs four functions (Times – Atomizes – Meters – Pressurizes):

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

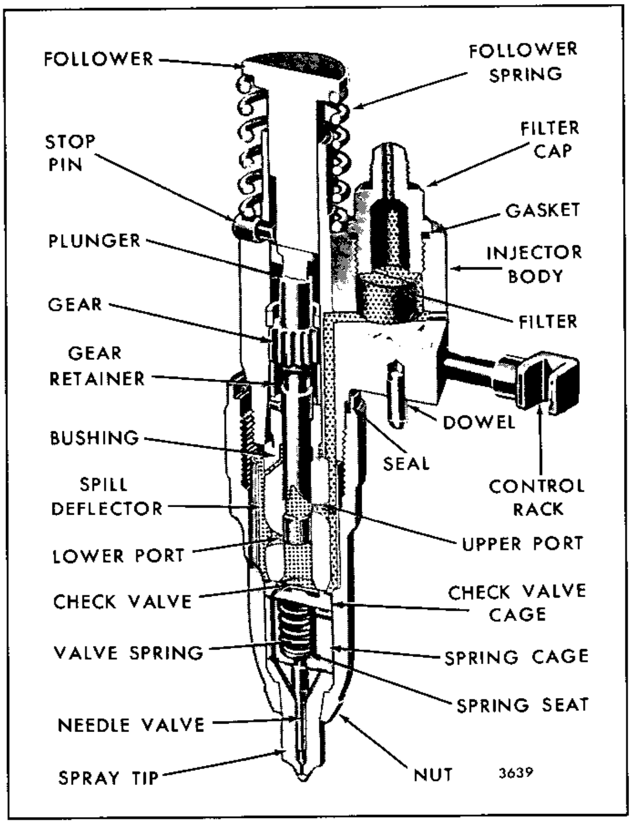


Fig. 2 – Cutaway View of Fuel Injector

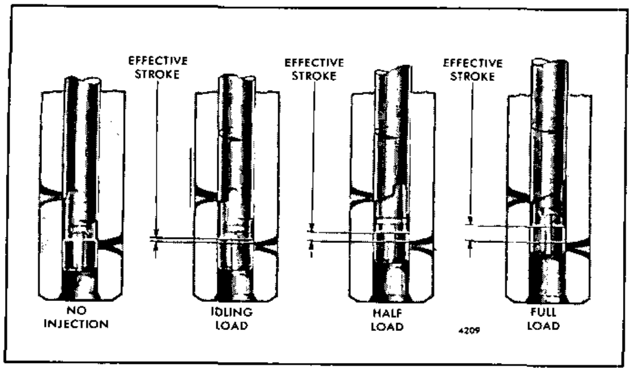


Fig. 3 – Fuel Metering from No Load to Full Load

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. (Fig. 3) illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

(Fig. 4) illustrates the phases of injector operation by the vertical travel of the injector plunger.

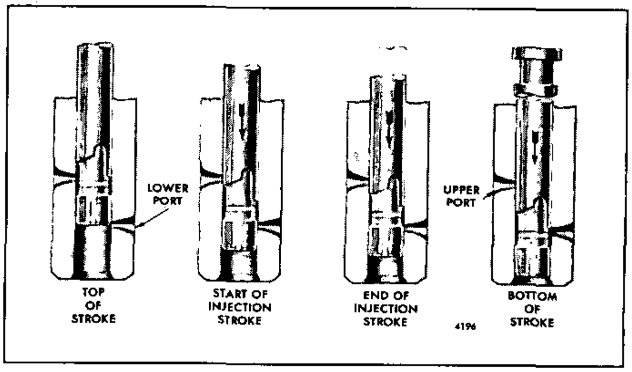


Fig. 4 – Phases of Injector Operation Through Vertical Travel of Plunger

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 1).

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting or fine tuning of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

- New O–ring sealed fuel pipes are used on the mechanical unit injectors in marine engines, effective with units built approximately April, 1988. These fuel pipes feature a three–piece connector (collar, nut, o–ring seal) at both ends (Fig. 38). The primary sealing element is the replaceable fluoroelastomer (Viton) O–ring seal.

- To conform with this change, new connectors are installed in the cylinder head and new fuel injectors with redesigned filter caps are used. The connectors and caps have a 1/2″ – 20 female thread to accept the 1/2″–20 male thread on the fuel pipe nuts.

- Flared tube design and O–ring design fuel pipes are not interchangeable on a part–for–part basis. The new pipes, connectors, and injector filter caps must be used together to insure interchangeability. The injector filter cap is not compatible with the former nylon cone fuel inlet filter. It must be used with the current stainless steel mesh pellet filter.

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the racks (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel–shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 5). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed–off of fuel leaking past the needle pilot in the tip assembly.

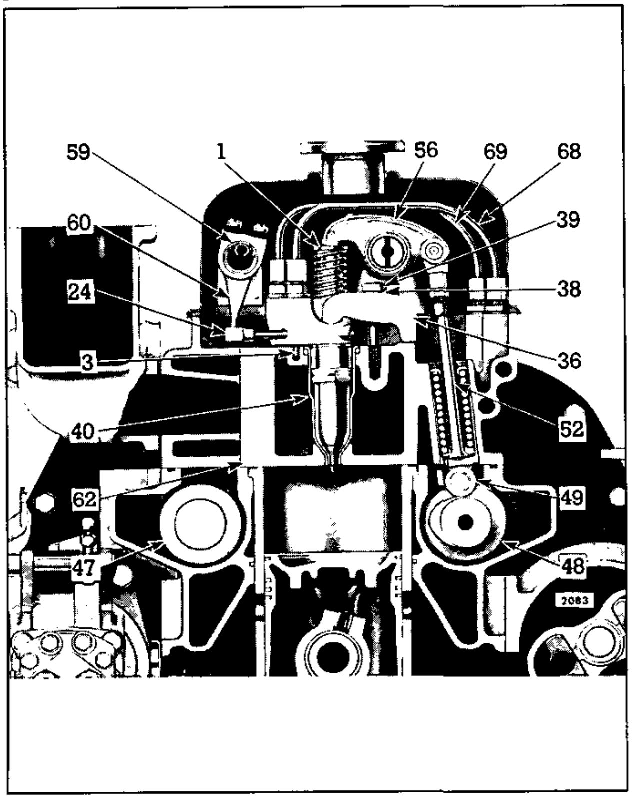


Fig. 5 – Fuel Injector Mounting

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its *original* position by the injector follower spring. (Fig. 4) shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. (Fig. 3) shows the various plunger positions *from no load to full load*. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this *no injection* position to *full injection* position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first–class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water–free fuel are the keys to trouble–free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the

doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.
2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and overhaul of an injector.
3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:
   a. Time the injector.
   b. Position the injector control rack.
4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Section 15.3).
5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

   NOTICE: Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.
2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 5).

   NOTICE: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also, protect the fuel pipes and fuel connectors from entry of dirt or foreign material.
3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation because the bolt could be loosened.

   CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.
4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 6).
5. Remove the injector clamp bolt, special washer and clamp.
6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

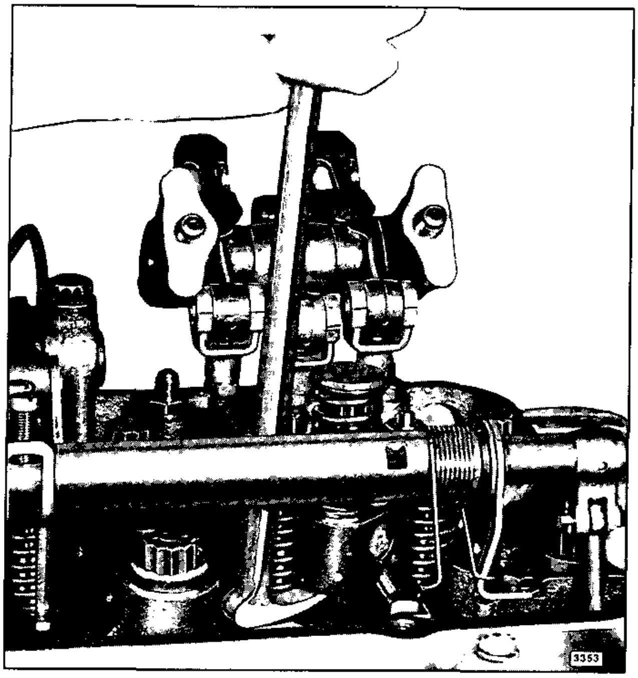


Fig. 6 – Removing Injector from Cylinder Head

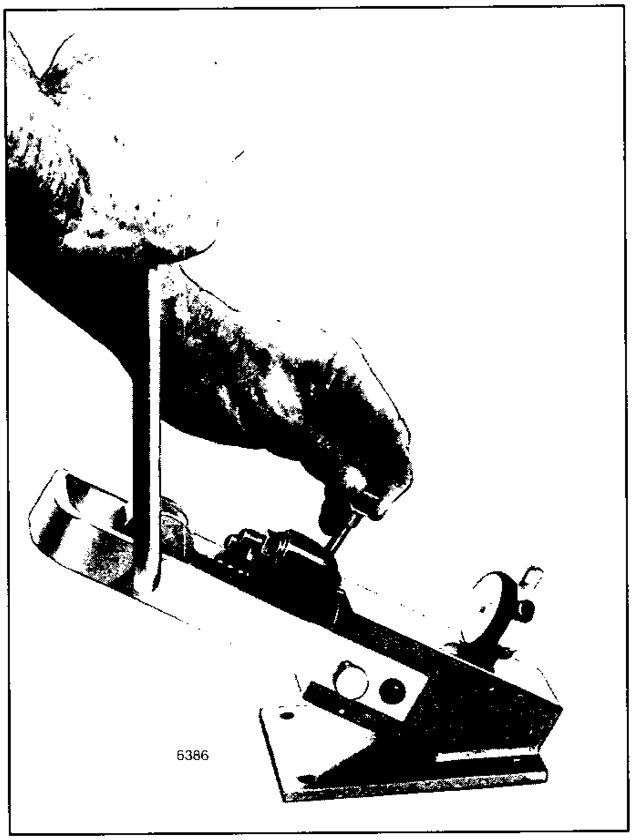


Fig. 7 – Checking Rack for Freeness in Tester J 29584

7. Lift the injector from its seat in the cylinder head (Fig. 6).

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect and Test Prior to Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrosion.
   - Follower spring
   - Injector body
   - Body nut
   - Spray tip
   - Injector rack
   - Filter caps
2. Inspect the following parts for wear or abrasion deterioration.
   - Top of the follower
   - Follower spring
   - Injector body
   - Spray tip orifices
3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 7). If the rack falls freely, the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.
4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

   If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 8) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 9).
2. Compress the follower spring (Fig. 10). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

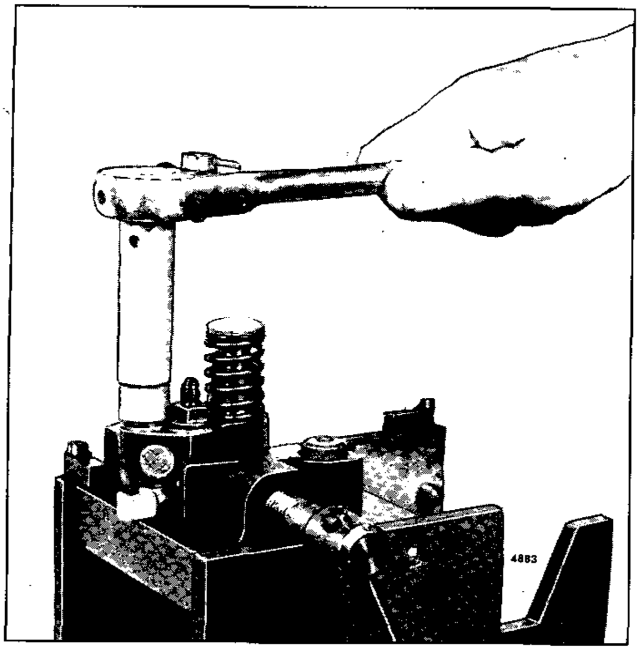


Fig. 8 – Removing Filter Cap

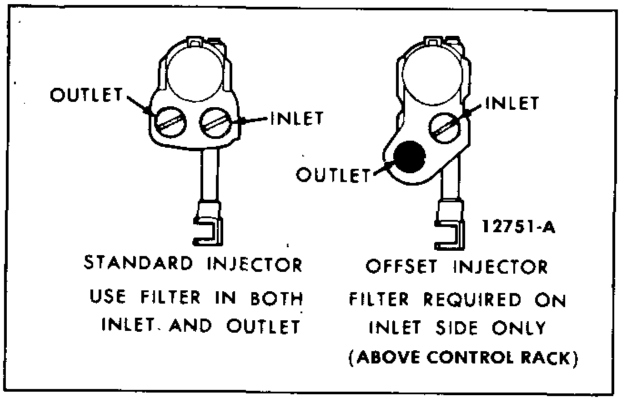


Fig. 9 – Location of Filter in Injector Body

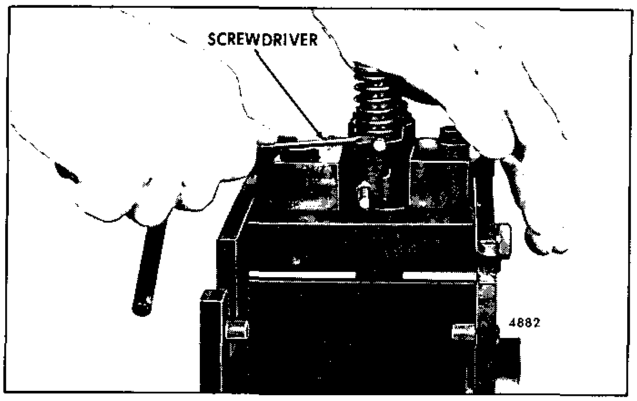


Fig. 10 – Removing Injector Follower Stop Pin

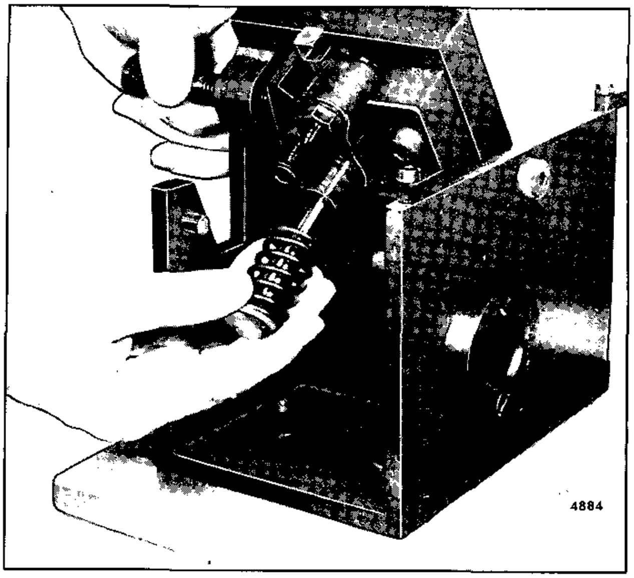


Fig. 11 – Removing or Installing Plunger Follower, Plunger and Spring

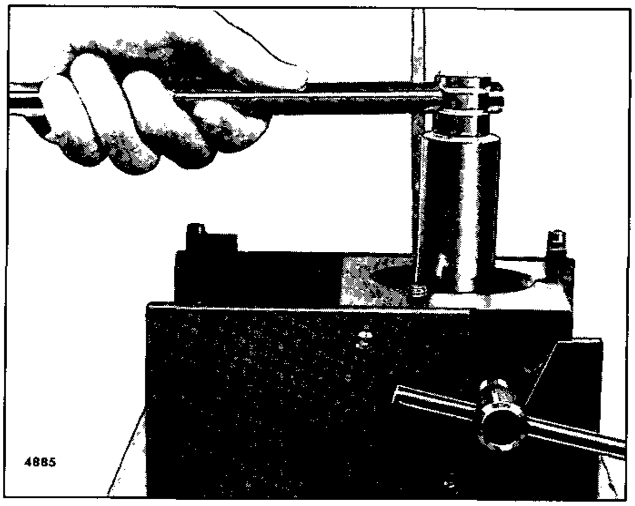


Fig. 12 – Removing Injector Nut Using Tool J 4983-01

3. Refer to (Fig. 11) and remove the plunger follower, plunger and spring as an assembly.

4. Using socket J 4983–01, loosen the nut on the injector body (Fig. 12).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip, spring cage, valve spring, spring seat, check valve cage and check valve.

When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the

 May, 1990

tip down through the nut, using tool J 1291–02 (Fig. 13).

6. Refer to (Fig. 14) and remove the spill deflector. Then, lift the bushing straight out of the injector body.

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Also, remove the seal ring from the body.

Clean Injector Parts

Since most injector problems are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with a suitable cleaning solvent and dry them with clean, filtered compressed air. Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

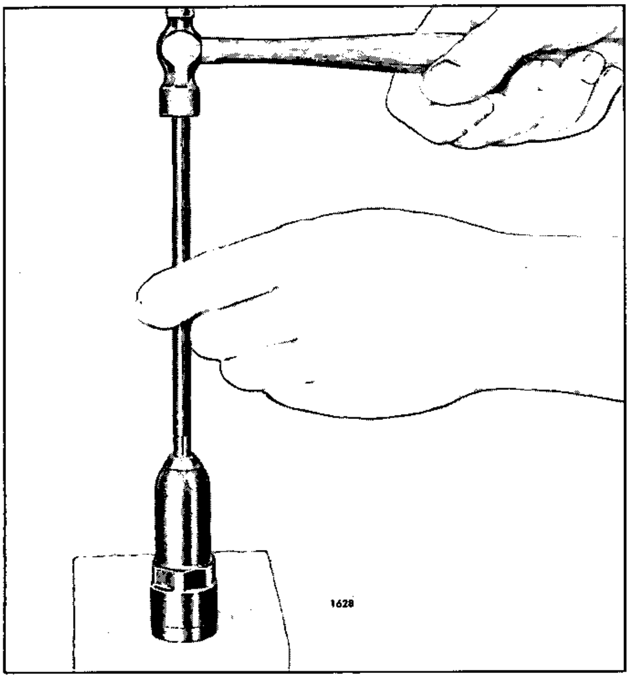


Fig. 13 – Removing Spray Tip from Injector Nut Using Tool J 1291–02

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately fifteen (15) minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with tool J 24838 (Fig. 15).

NOTICE: Care must be exercised when inserting the carbon remover J 24838 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298–1 and the proper size spray tip cleaning wire. Use wire J 21460–01 to clean .0055″ diameter holes and wire J 21461–01 to clean .006″ diameter holes (Fig. 16).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16″ with stone J 8170. Allow the wire to extend 1/8″ from tool J 4298–1. Ultra sonic cleaning is also an acceptable method.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 24838 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully, insert reamer J 21089 in the injector body (Fig. 17). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

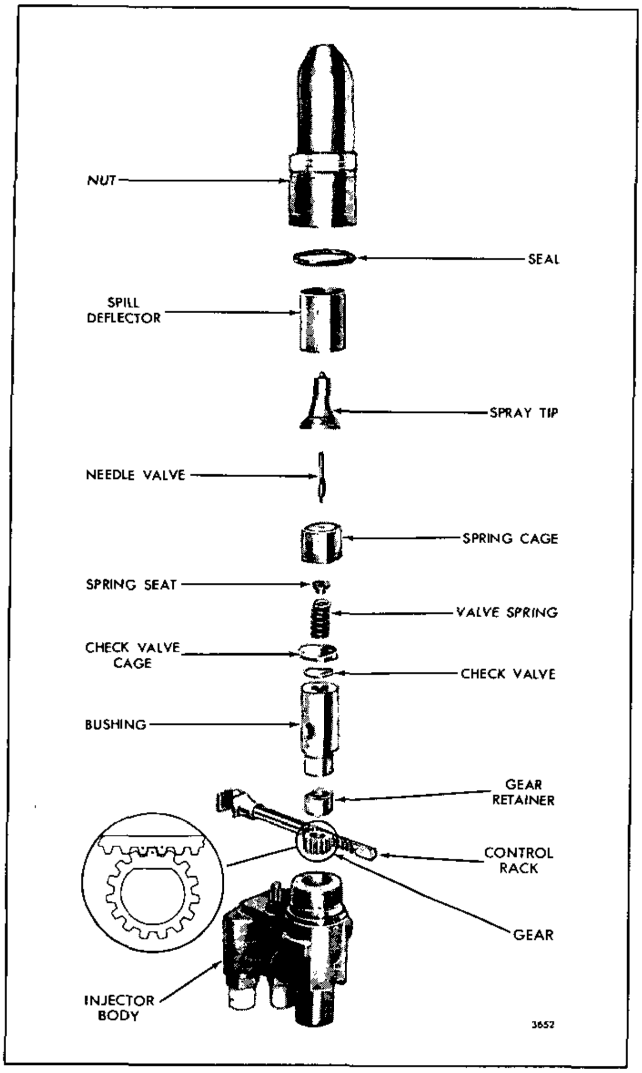


Fig. 14 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

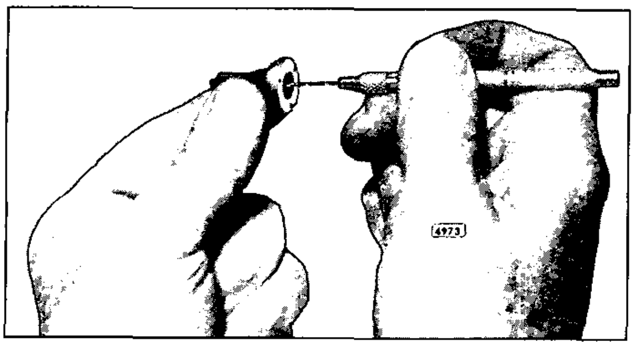


Fig. 15 – Cleaning Injector Spray Tip with Tool J 24838

Carefully, insert reamer (J 21089) into the ring bore of the injector body. Turn the reamer in a clockwise direction

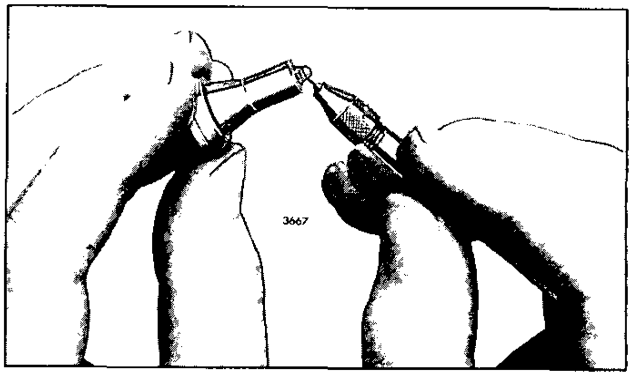


Fig. 16 – Cleaning Spray Tip Orifices with Tool J 4298-1

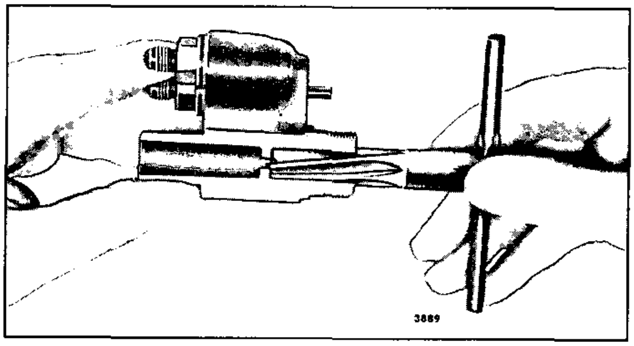


Fig. 17 – Cleaning Injector Body Ring with Tool J 21089

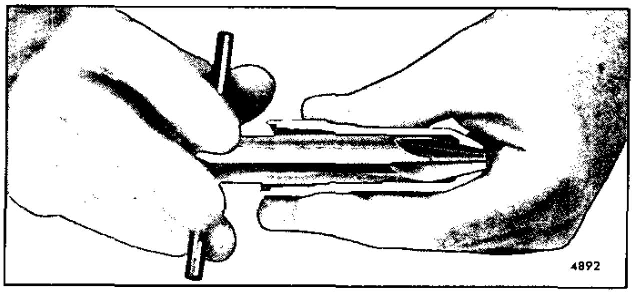


Fig. 18 – Cleaning Injector Nut Lower End with Tool J 9418-5

and remove any burrs inside the ring bore. Then, wash the injector body in clean solvent and dry it with compressed air.

- **NOTICE:** Do not damage the injector body ring during this operation. This spiral ring forms part of the injector body and is not serviced. If the ring is damaged, the injector body must be replaced.

Remove the carbon deposits from the lower end of the injector nut with reamer J 9418-5 (Fig. 18). Clean the tip seat with reamer J 9418-1. Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut.

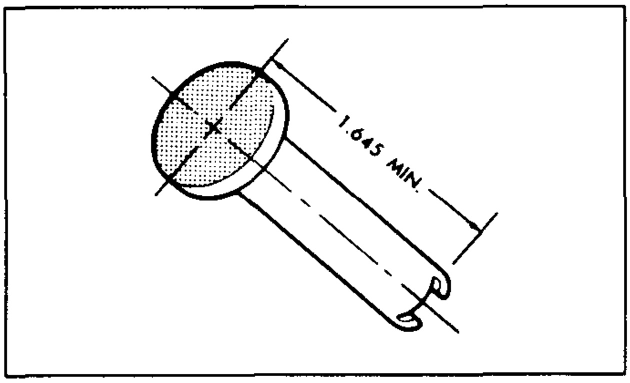


Fig. 19 – Injector Follower

Wash the injector nut in clean solvent and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. *Keep the plunger/bushing together as they are matched parts.*

After washing, submerge the parts in a clean receptable containing clean test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual and Dimensional)

1. Follower

   Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002″ (Fig. 19).

   Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002″ wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 29196.

   The current injector follower spring (.142″ diameter wire) has a free length of approximately 1.504″ and should be replaced when a load of less than 70 lbs. will compress it to 1.028″. The former spring wire was .120″ diameter.

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.142″ diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces for damage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Cap:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125″ to .3145″. A .250″ inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

• 7. & 8. Plunger and Bushing Assembly:

- Effective with injectors manufactured in October, 1985, the P & B (plunger and bushing) assemblies of all fuel injectors have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation.
- Revised P & B assemblies are identified with a black locating pin at the top of the bushings. Injector assemblies containing revised P & B's are date stamped on the body with a "10–85" (for October, 1985) or later build date. Revised P & B assemblies are physically interchangeable with early P & B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.
- **NOTICE:** Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise–versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

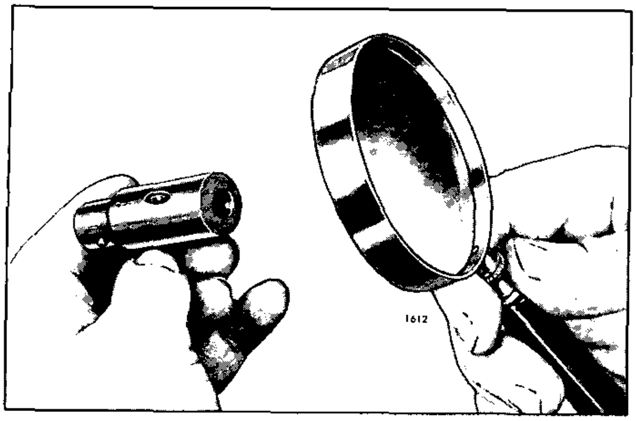


Fig. 20 – Examining Sealing Surface with a Magnifying Glass

7. Bushing:

   Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 20).

8. Plunger:

   Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Fig. 21).

9. Check Valve:

   Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.

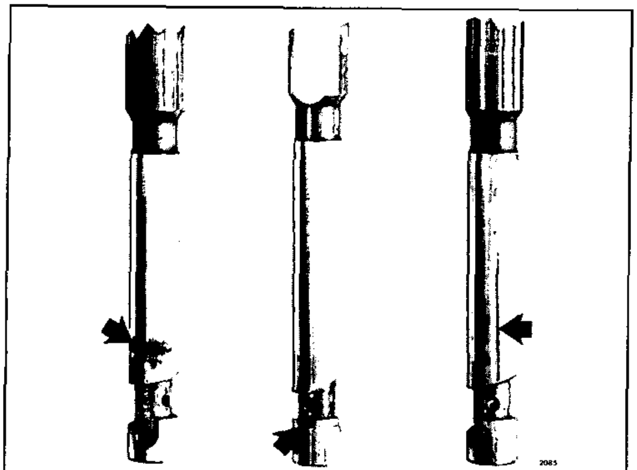


Fig. 21 – Unusable Injector Plungers

10. Check Valve Cage:

    Inspect the check valve cage for cracks and scratches on the lapped surfaces or for corrosion, varnish and wear.

11. Valve Spring:

    Check the injector valve spring for wear on the coil ends, broken coil ends and notches under the coil ends. Then, check for corrosion, nicks and cavitation erosion on the inside at approximately 1–1/2 coils from the end.

- **NOTICE:** A high V.O.P. (valve opening pressure) valve spring and seat are being used in certain high output engine injectors. The high V.O.P. spring is made of a thicker diameter wire than the standard valve spring and has a smaller inside diameter (.174" I.D. vs .184" I.D.). A no. 15 (.180") drill may be used to distinguish the two springs. The drill will fit into the standard spring, but not into the high V.O.P. spring. The high V.O.P. spring seat can be distinguished from the standard spring seat by its smaller diameter post and the groove on the end of this post. To ensure proper operation, the high V.O.P. spring and seat must be used together. *Do not mix injectors containing standard springs and seats with injectors having high V.O.P. springs and seats in the same engine.*

12. Spring Seat:

    Check the surfaces for wear.

13. Spring Cage:

    Inspect for cracks, corrosion or varnish and scratches on the lapped sealing surfaces. Also, inspect the spring seat surface and the needle valve seating surface for wear.

14. Spray Tip:

    Check for cracks, enlarged spray holes, corrosion on the outside diameter taper and oxide scale on the spray hole end. Then, check the nut–to–tip sealing surface and the lapped sealing surface for scratches. Do not reuse if there is scale, cracks or enlarged spray holes.

15. Needle Valve:

    Check the spray tip needle valve for erosion at the seat shoulder, scratches and overheating (discolored).

16. Nut:

    Check the nut for damaged threads, the condition of the seal ring seating area, the condition of spray tip seating area and the spray tip hole for being corroded irregularly.

17. Spill Deflector:

    Inspect both ends of the spill deflector for sharp edges or burrs.

18. Part Thickness:

Check the minimum thickness of the parts (see Table 1).

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163"—.165"
Check Valve	.022"
Valve Spring Cage	.602"

TABLE 1 – MINIMUM THICKNESS (Used Parts)

19. Needle Valve Lift:

Measure the needle valve lift, using tool J 9462–02 (Fig. 22) as follows:

a. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

b. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

c. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be .008" to .018". If it exceeds .018", the tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

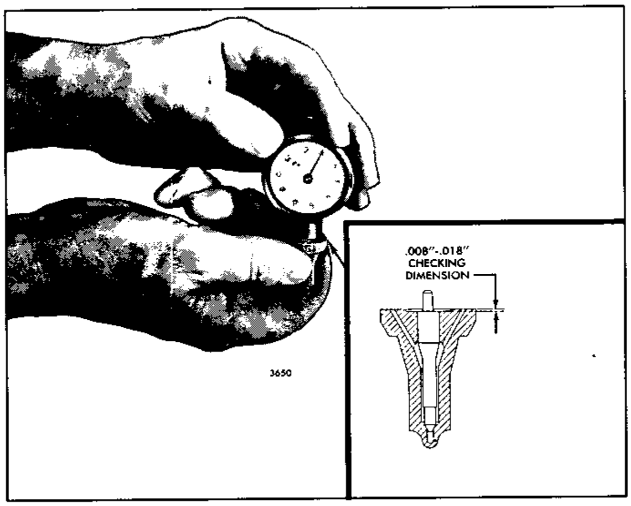


Fig. 22 – Checking Needle Valve Lift with Tool J 9462–02

d. If the needle valve lift is within limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.

20. Classify Spray Tip:

Match the plunger/bushing assembly with the proper spray tip using Flow Gage J 25600–A (see Section 2.0).

Recondition Injector

If any of the injector parts listed below cannot be reconditioned satisfactorily, use new parts. Al parts must be cleaned to be free of rust, varnish and carbon before reuse.

1. Follower:
   - Resurface or replace if worn beyond dimensional limits.
2. Follower Spring:
   - Reuse unless damaged, worn or won't meet test specifications.
3. Body:
   - Lap bushing seat.
   - Reblue.
   - Repair damaged threads.
   - Replace body if the clamp radius is badly worn or if the threads are less than 90% good.
4. Filter Caps:
   - Recondition tapered seat.
   - Clean and deburr hole.
   - Reblue.
   - Replace if the threads or sealing surfaces are damaged.
5. Control Rack:
   - Deburr teeth – check for straightness.
   - Replace if the teeth show significant wear.
6. Gear and Gear Retainer:
   - Deburr.
   - Replace if cracked or significantly worn.
7. Bushing:
   - Replace if scored, cracked or if residue cannot be removed.
   - Lap the check valve seat (sealing) surface.
8. Plunger:
   - Clean – remove varnish.
   - Replace if scored, chipped or scratched.
9. Check Valve:
   - Lap both flat (sealing) surfaces.
   - Replace if scratched, cracked or badly worn.

10. Check Valve Cage:
    - Lap both flat sealing surfaces.
    - Replace if cracked or too thin (see Table 1).
11. Valve Spring:
    - Replace. Do not reuse unless there is absolutely no wear or damage.
12. Spring Seat:
    - Replace if there is a hole worn in the rounded end where the needle quill touches.
13. Spring Cage:
    - Lap both flat (sealing) surfaces.
    - Replace if cracked or too thin (see Table 1) or if the needle has worn a pocket around the small hole.
14. Spray Tip:
    - Regrind seat.
    - Lap flat sealing surface.
    - Regrind the needle conicol seat.
    - Replace if beyond flow limits i.e., eroded spray holes.
15. Nut:
    - Remove carbon from the seat and tapered I.D.
    - Reblue.
    - Replace if the threads are damaged more than 10% or if the small I.D. is badly eroded.
16. Spill Deflector:
    - Remove burrs.
    - Reuse if the ends are smooth and even and the deflector is not cracked.

Normally, new parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solitified preservative. However, if new parts become nicked or burred during handling, then lapping will be necessary to provide adequate sealing between the flat parts.

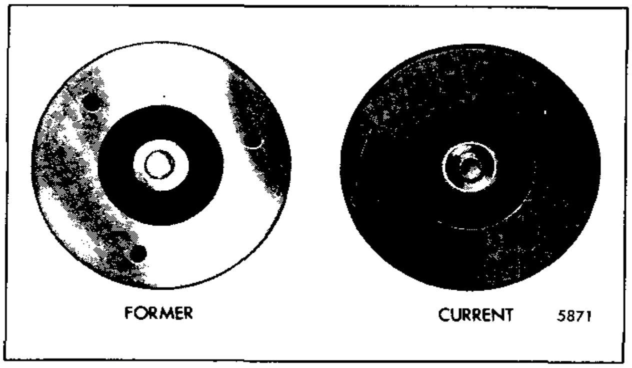


Fig. 23 – Spray Tip Sealing Surface Identification

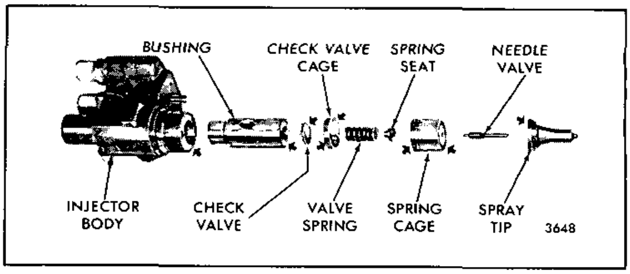


Fig. 24 – Sealing Surfaces which May Require Lapping

The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin–like finish; the lapped surface on former spray tips was bright and shiny (Fig. 23). DDC does not recommended lapping the surface of a *new* current spray tip.

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in (Fig. 24) as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
3. Place the part to be lapped flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*
5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

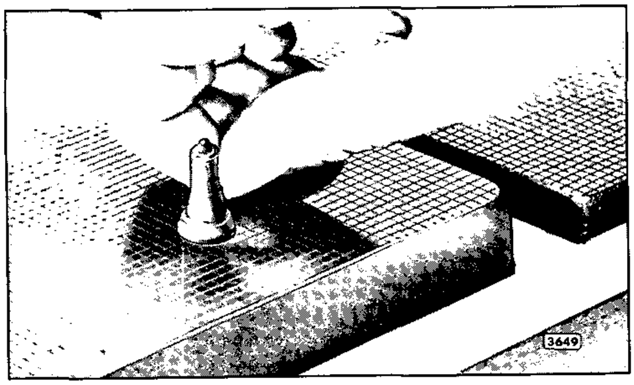


Fig. 25 – Lapping Spray Tip on Lapping Blocks J 22090

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in cleaning solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Injector

1. Secure the body in vise J 22396–1.

• 2. Insert new filter(s) in the top of the body (Fig. 26). The current production service filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The former service filter (fiberglass–filled nylon cone) was installed with the pointed (cone) end up.

Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).

• 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten injector filter caps with a 9/16" deep socket as follows:

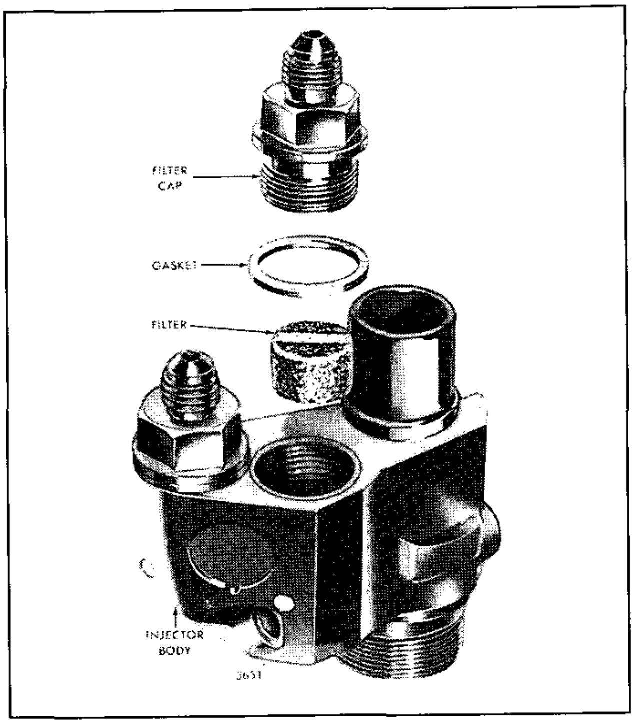


Fig. 26 – Details of Injector Filters and Caps and Their Relative Location

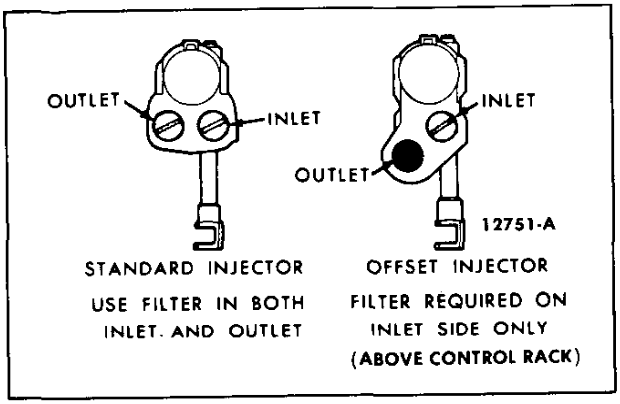


Fig. 27 – Location of Filter in Injector Body

Non–blued cap on non–blued body . . . . 62 lb–ft (84 N·m) torque

Blued cap on blued body . . . . 70 lb–ft (95 N·m) torque

Non–blued cap on blued body or blued cap on non–blued body . . . . 62 lb–ft (84 N·m) torque

Cap for O–Ring sealed fuel pipe . . . . 70 lb–ft (95 N·m) torque

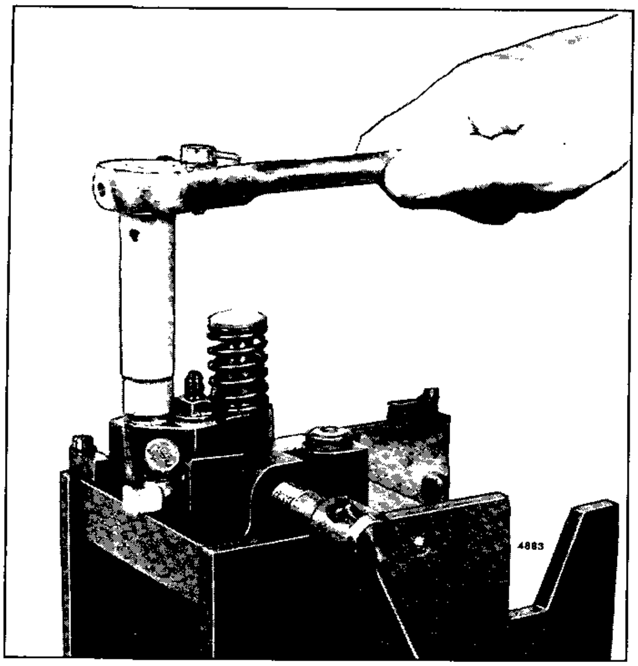


Fig. 28 – Installing Filter Cap

4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.

5. Lubricate the injector nut seal ring installer J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the installer over the threads of the injector body.

6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

- A new round (in cross–section) injector nut seal ring replaced the former diamond–shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal ring is serviced.

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

9. Refer to (Fig. 29) and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

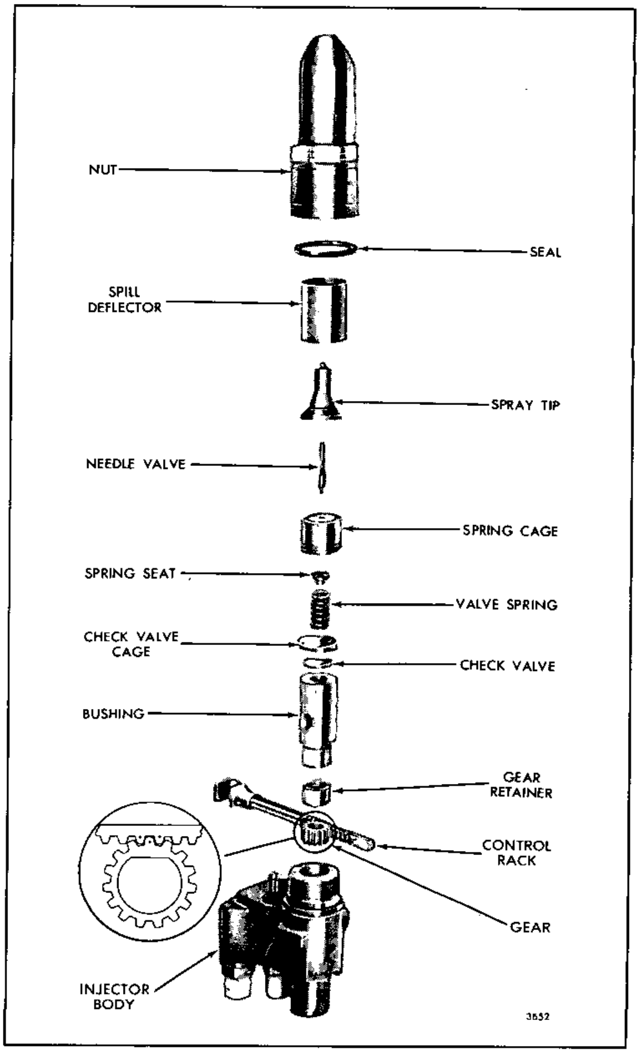


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396–1.

14. Install the spill deflector over the barrel of the bushing.

15. Perform the spray tip test, as outlined in Section 2.0 using injector tip Tester J 22640–A before proceeding with the injector assembly.

16. Place the check valve (without the .010″ hole) centrally on the top of the bushing. Then, place the check valve cage over the check valve and against the bushing. The check valve cage must not rest on the check valve.

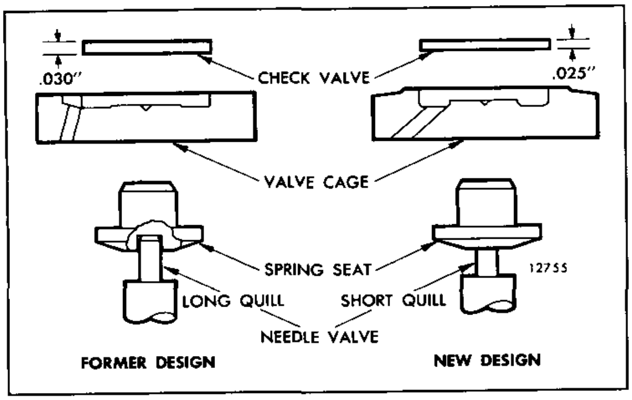


Fig. 30 – Comparison of Former and New Design Injector Parts

The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 30).

17. Insert the spring seat in the valve spring, then insert the assembly into the cage, spring seat first.

18. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

    Do not use new design needle valve spray tip with former design spring seat (Fig. 30).

19. Put the needle, tapered end down, into the spray tip (Fig. 31). Then, place the spray tip assembly on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

20. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 32). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

• 21. Use socket J 4983–01 and a torque wrench to tighten the injector nut as follows:

    Non–blued nut on
    non–blued body .... 50 lb–ft (68 N·m) torque

    Blued nut on
    blued body .... 80 lb–ft (108 N·m) torque

    Non–blued nut on blued
    body or blued nut on
    non–blued body .... 65 lb–ft (88 N·m) torque

22. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

NOTICE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

23. Turn the injector over and push the rack all the way in.

24. Place the follower spring on the injector body.

25. Refer to (Fig. 34) and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.

26. Refer to (Fig. 35) and slide the head of the plunger into the follower.

27. Align the slot in the follower with the stop pin hole in the injector body.

28. Align the flat side of the plunger with the flat in the gear.

29. Insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

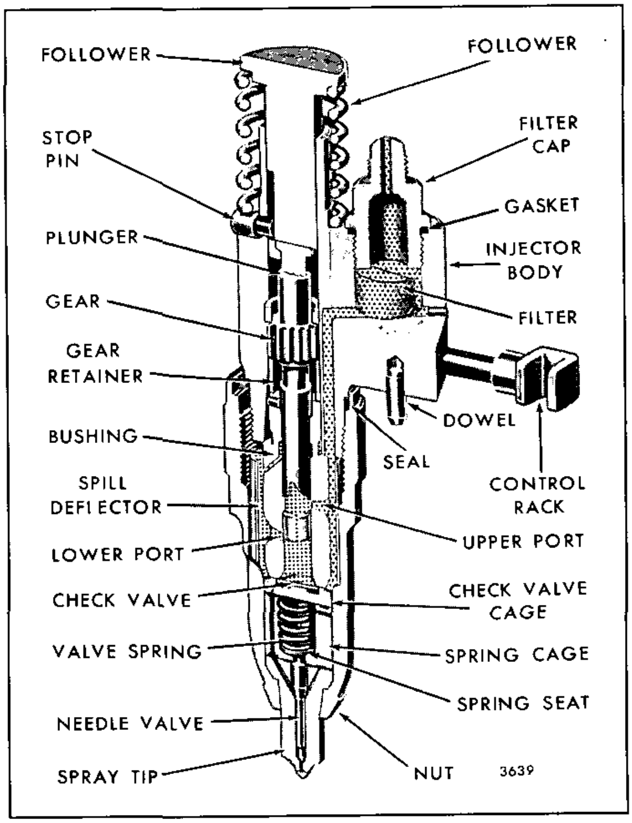


Fig. 31 – Cutaway View of Fuel Injector

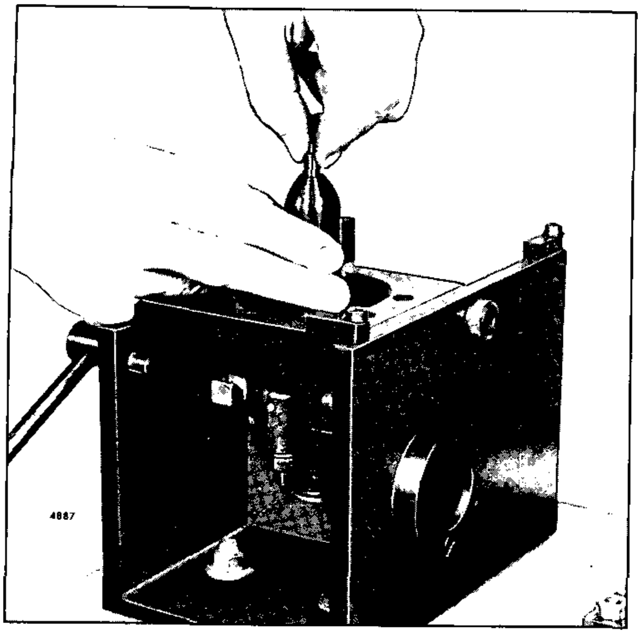


Fig. 32 – Tightening Injector Nut by Hand

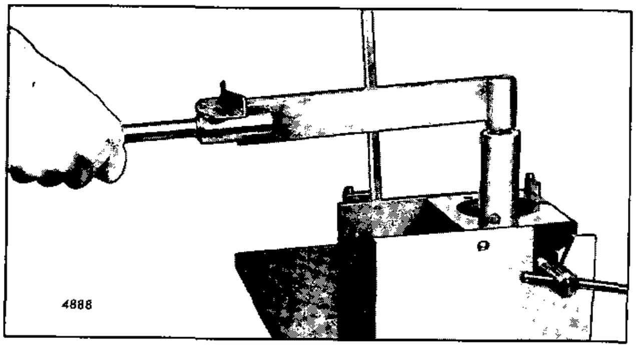


Fig. 33 - Tightening Injector Nut with Torque Wrench Using Tool J 4983–01

Check Injector Output

Perform the injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

Check Atomization and Spray Pattern

This test determines spray pattern uniformity and atomization.

1. Clamp the injector properly and purge the air from the system (Fig. 36).
2. Move lever 4 down.
3. Position the injector rack in the *full–fuel* position.
4. Place pump lever 1 in the *vertical* position.
5. Move lever 3 to the *forward detent* position.
6. The injector follower should be depressed rapidly using pump lever 1 (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

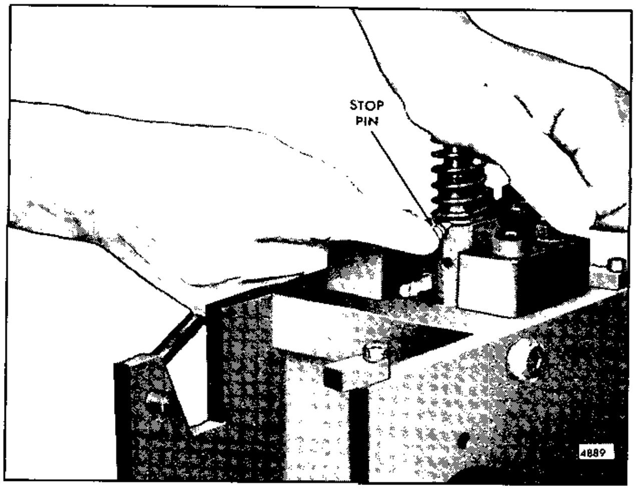


Fig. 34 – Installing Injector Follower Stop Pin

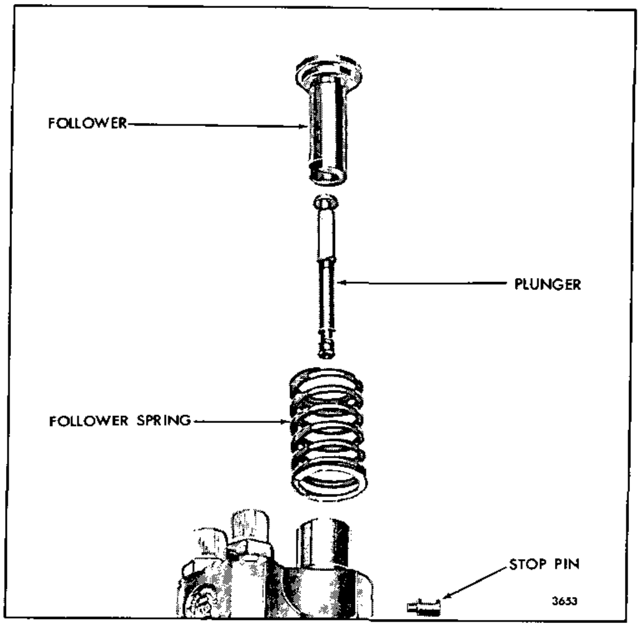


Fig. 35 – Injector Plunger, Follower and Relative Location of Parts

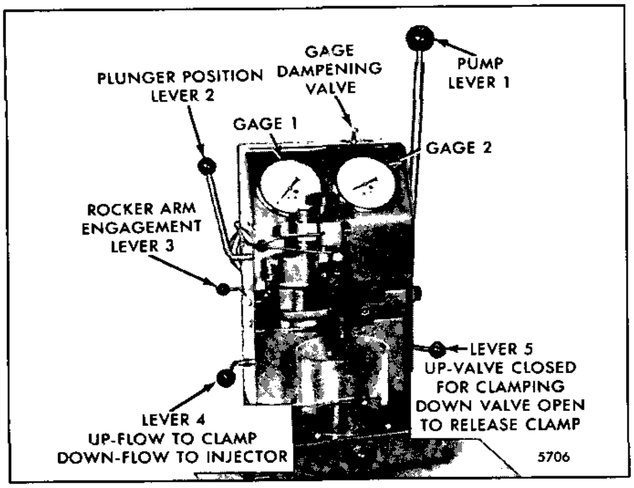


Fig. 36 – Injector in Position for Testing with Tester J 23010–A

Check Pressure Holding and Test for Leaks

This test determines if the body–to–bushing mating surfaces in the injector are sealing properly and indicates proper plunger–to–bushing fit.

1. Clamp the injector properly in Tester J 23010–A and purge the air from the system (Fig. 36).
2. Close the Thru–Flow valve, but do not overtighten.
3. Move lever 2 to the rear, *horizontal* position.
4. Operate pump lever 1 until gage 1 slowly reaches 100–200 psi (689–1378 kPa), check for injector nut seal ring leaks. Then, increase the gage reading to 1500–2000 psi (10 335–13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs. Note the time for the pressure to drop from 1500 psi to 1000 psi (10 335 kPa to 6890 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.
5. Unclamp the injector.
6. Open the Thru–Flow valve to release pressure in the system.
7. Move lever 5 *down* to release the clamping pressure.
8. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.
9. Carefully, return lever 5 to the *up (horizontal)* position.

Check Rack Freeness and Spray Tip Concentricity

Place the injector in Tester J 29584 (Fig. 37) and check rack freeness.

With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel. If the rack falls freely the injector passes the test.

If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times, if necessary. Generally, this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts or to remove dirt.

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 29584 (Fig. 37) and adjust the dial indicator to zero.

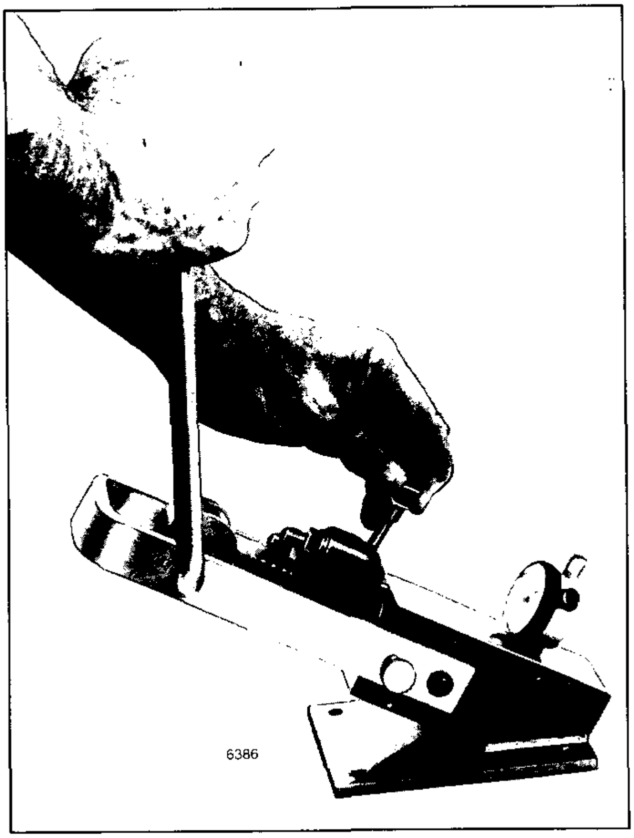


Fig. 37 – Checking Rack for Freeness in Tester J 29584

2. Rotate the injector 360° and note the total runout as indicated on the dial.

3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 75–85 lb–ft (102–115 N·m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box and Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylindrical wire brush, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrusion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to (Fig. 5) and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

2. Slide the injector rack control lever over so that it registers with the injector rack.

3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb–ft (27–34 N·m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0 – Specifications.

   NOTICE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridge before, during and after tightening the rocker shaft bolts.

5. Install fuel pipes:

   - *A. Flared end fuel pipes.* Remove the injector shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

   NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 ***lb–in*** (14.69 N·m) torque, instead of the 160 lb–in (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

NOTICE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks in Section 2.0 – Shop Notes).

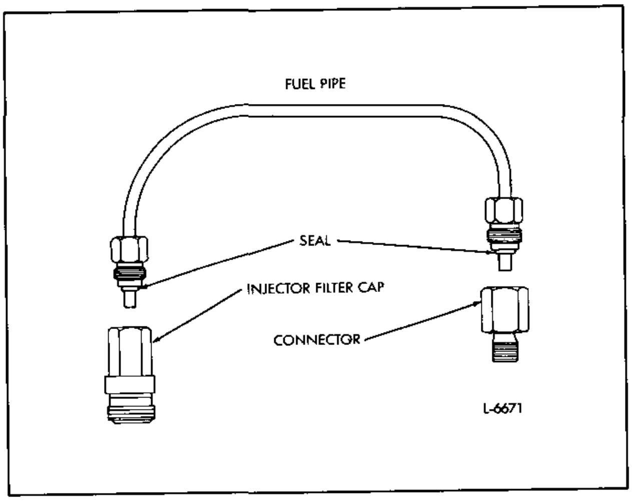
An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Use a new gasket and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

- *B. O–ring sealed fuel pipes.* Inspect fuel pipes and connectors (Fig. 38) carefully. Fuel pipes may be reused if they are not twisted, bent, distorted or otherwise damaged. O–ring design fuel pipes are not interchangeable with flared tube design fuel pipes on a part–for–part basis. O–ring design fuel pipe connectors and injector filter caps have a 1/2" – 20 female thread to accept the 1/2" – 20 male thread on the fuel pipe nuts. These parts *must* be used together to insure interchangeability.

NOTICE: To avoid fuel leakage, always use new O–ring seals when replacing the fuel pipes on an engine. Do not reuse seals.

Remove the injector shipping caps. Align the fuel pipes and connect them to the injector filter caps and the cylinder head connectors. Using "clicker" type torque wrench J 24405 (calibrated in inch–pounds), tighten the O–ring sealed fuel pipe nuts to 143 ***lb–in*** (16.16 N·m) torque.

6. Perform a complete engine tune–up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.



- Fig. – 38 O–Ring Sealed Fuel Pipes, Connectors, Injector Filter Caps

FUEL INJECTOR TUBE

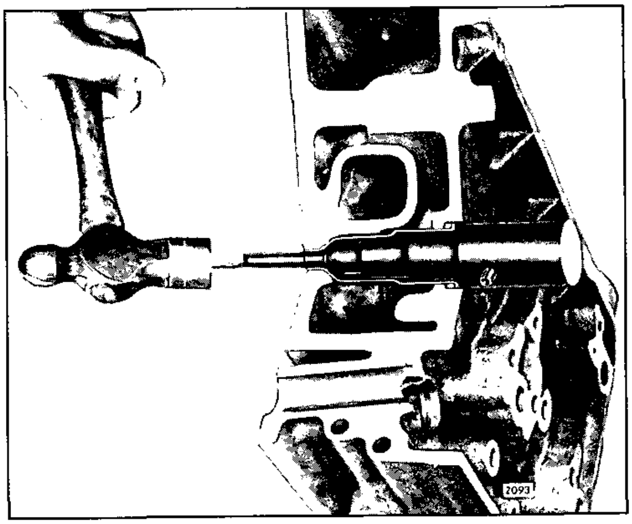


Fig. 1 – Removing Injector Tube Using Tools J 5286–4A and J 5286–5

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring (former) or fluorelastomer (current) and upset into a flare on the lower side of the cylinder head to create water–tight and gas–tight joints at the top and bottom.

- The new service–only injector hole tube can be distinquished from the former by the size of the large I.D. (1.198″–1.201″ vs. 1.180″ –1.183″) and by the Detroit Diesel logo plus the number "606" stamped on the top flange. The former tube was marked with either "GM" or the Detroit Diesel logo on the top flange.

- The new tube takes less time to install than the former tube because the larger I.D. (inside diameter) of the new tube does not require reaming. Reaming is only necessary at the small I.D. and the injector nut seat. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

> **NOTICE:** Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base antifreeze is not recommended because of its effect on the fluoroelastomer seal rings in the cylinder head.

• Repair Leaking Injector Tube

To permit the repair of a leaking fuel injector hole tube at the seal ring, without removing the cylinder head from the cylinder block, a new injector hole tube swaging tool J 28611–A is available.

Before removing the fuel injector, pressurize the cooling system at the radiator to verify the injector tube seal ring leak. Then, with the fuel injector removed, insert the swaging tool into the fuel injector hole tube. The tool is tapered and flanged to prevent damage to the cylinder head or injector tube. Hit the top of the tool moderately with a one pound hammer two or three blows, seating the tool. This will cause the top edge of the injector hole tube to expand, thus increasing the crush on the injector tube seal ring and seal the leak. Install the fuel injector and again pressurize the cooling system to verify the leak has been stopped.

This tool was designed mainly for use on engines built between July, 1973 and August, 1977 with fuel injector hole tube seal rings that may be pressure sensitive and, if so, could take a heat set. The result being a coolant leak at the seal ring.

The use of the swaging tool, as stated above, will restore tension the the seal ring.

Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

1. Remove, disassemble and clean the sylinder head, as outlined in Section 1.2.
2. Place the injector tube installer J 5286–4A in the injector tube. Insert the pilot J 5286–5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1).
3. Tap on the end of the pilot to loosen the injector tube. Then lift the injector tube, and pilot from the cylinder head.

Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Then, install the tube as follows:

1. Lubricate the new injector tube seal ring with engine oil and place it in the counterbore in the cylinder head.

> **NOTICE: DO NOT** lubricate the outside of the injector tube or inside the cylinder head injector tube bore to facilitate installation of the tube. Lubricant will cause the tube to turn during reaming or rolling operations possibly damaging the injector tube or reamers.

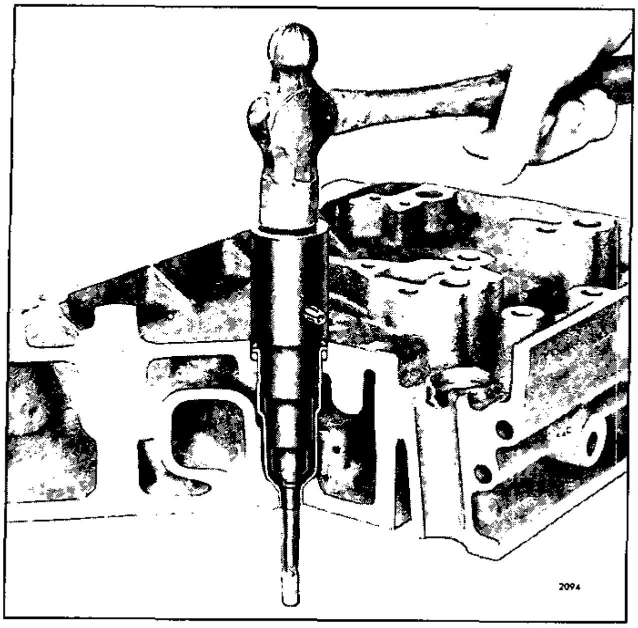


Fig. 2 – Installing Injector Tube Using Tools J 5286–4A and J 5286–5

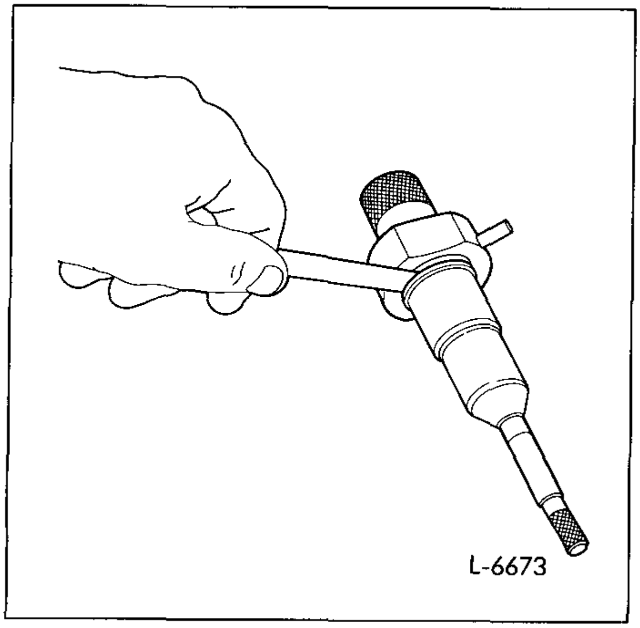


Fig. 3 – Measuring Clearance Between Installation Tool and Top of Hole Tube Flange

● 2. Place the installer J 5286–4C in the injector tube. Then, insert the pilot J 5286–5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2). For proper installation of any injector hole tube, the tool must contact the tube at the bottom before it touches the flange at the top. The clearance at the top, between the flange and the tool, should be .001" to .010" (Fig. 3).

3. Slip the injector tube into the injector bore and drive it in place (Fig. 2). Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

- During installation the tube will stretch slightly before the tool contacts the flange, thus allowing the tool to properly install the tube. If there is no clearance at the flange, the tube will buckle slightly during installation until the tool contacts the tube at the lower end. The buckling causes compressive stress which will result in tube cracking during engine operation and subsequent engine damage.

  It is permissable for the tube flange at the O–ring seal end to protrude up to .120" above the cylinder head casting without sealing being affected. Sealing is accomplished by compressing the O–ring seal between the head counterbore and the outside diameter of the injector tube. The tube flange is merely used to retain the seal ring in the head counterbore.

4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

   a. Turn the cylinder head bottom side up, remove the pilot J 5286–5 and thread the upsetting die J 5286–6 into the tapped end of the installer J 5286–4C (Fig. 4).

   b. Then, using a socket and torque wrench, apply approximately 30 lb–ft (41 N·m) torque on the upsetting die.

   c. Remove the installing tools and ream the injector tube as outlined below.

Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations:

First, *hand reamed,* as shown in Fig. 5, to receive the injector body nut and spray tip.

Second, *spot–faced* to remove excess stock at the lower end of the injector tube.

Third, *hand reamed,* as shown in Fig. 6, to provide a good seating surface for the bevel or the lower end of the injector nut.

● The new tube takes less time to install than the former tube because the large I.D. (inside diameter) of the new tube does not require reaming. Reaming is only necessary at the small I.D. and the injector nut seat. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

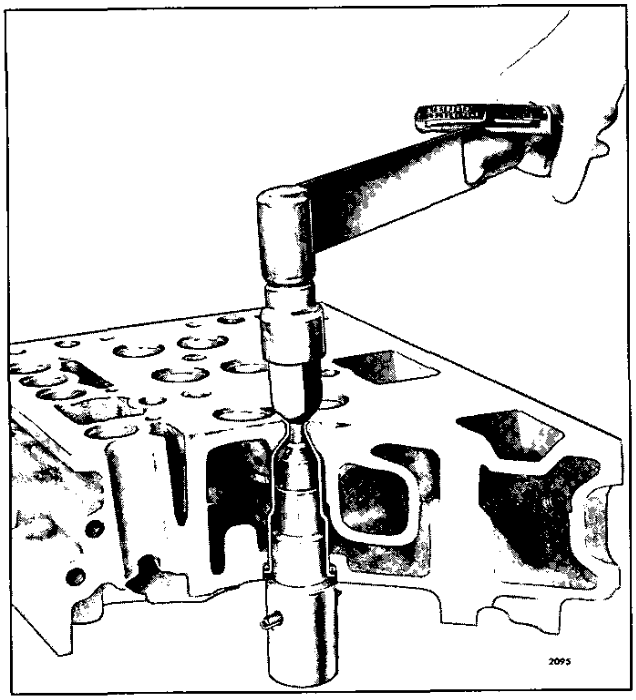


Fig. 4 – Upsetting Injector Tube Using Tools J 5286–4A and J 5286–6

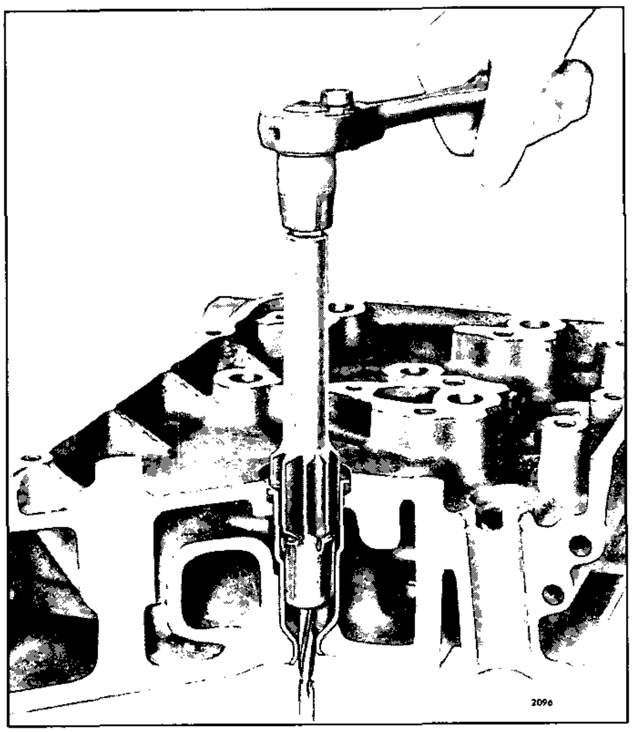


Fig. 5 – Reaming Injector Tube for Injector Body Nut and Spray Tip Using Tool J 22525–1

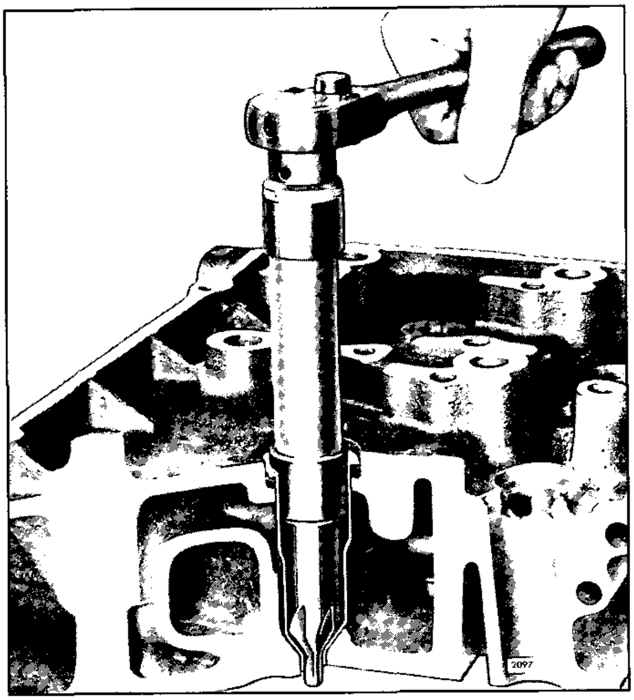


Fig. 6 – Reaming Injector Tube for Injector Nut Using Tool J 5286–9

NOTICE: The reamer should be turned in a *clockwise direction* only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the cutting edges of the flutes.

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

   a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525–1 in the injector tube.

   b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 5). Clean out all of the chips.

2. Remove excess stock:

   a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286–8 into the small hole of the injector tube.

   b. Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005" below the finished surface of the cylinder head.

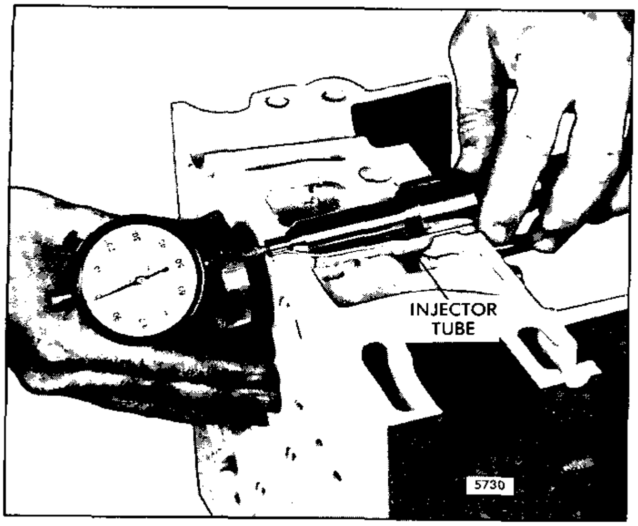


Fig. 7 – Measuring Relationship of Bevel Seat in Injector Tube to Cylinder Head Fire Deck Using Tools J 22273 and J 2

3. Ream the bevel seat in the injector tube:

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, refer to Fig. 7.

Install gage J 25521 in the injector tube. Zero the sled gage dial indicator J 22273 to the fire deck. Gage J 25521 should be flush to± .014" with the fire deck of the cylinder head (Fig. 8).

Any fire deck resurfacing work must be done prior to final injector tube seat gaging. Refer to Section 1.2 for resurfacing instructions.

With the first reaming operation completed and the injector tube spot–faced, wash the interior of the injector tube with clean solvent and dry it with compressed air.

- **CAUTION: To prevent possible injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Then perform the second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286–9 into the injector tube until it contacts the bevel seat.

b. Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.

c. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

d. Remove the chips from the injector tube and, using gage J 25521, continue the reaming operation until the shoulder of the spray tip is flush to± .014" with the fire deck of the cylinder head (Fig. 8). Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

- **CAUTION: To prevent possible injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

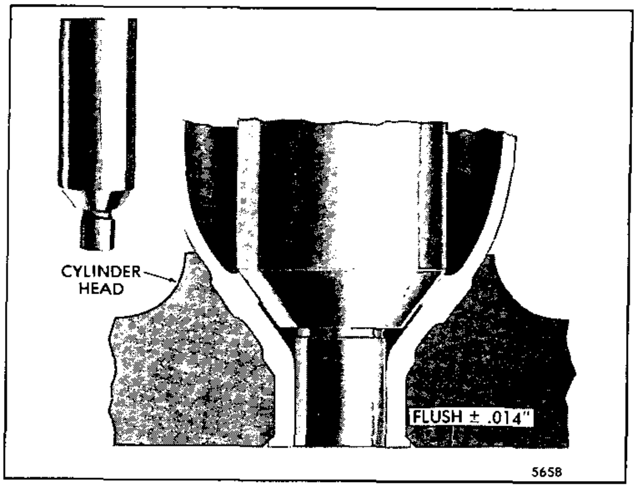


Fig. 8 – Measuring Relationship of Gage to Cylinder Head Fire Deck Using Tool J 25521

FUEL PUMP

The positive displacement gear–type fuel pump transfers fuel from the supply tank to the fuel injectors (Fig. 1). The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

On the In–line engine, the fuel pump is mounted on the governor weight housing and is driven through a drive coupling by the governor weight shaft. On the V–type engine, the fuel pump is mounted on the flywheel housing and is driven by the accessory drive gear.

Certain engine applications use a high–capacity fuel pump with 3/8" wide gears to increase fuel flow and reduce fuel spill temperature. The high–capacity fuel pump and the standard fuel pump with 1/4" wide gears may not be completely interchangeable; therefore, when replacing a standard pump with a high–capacity pump, the appropriate fuel lines and connections must be used.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal–to–metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

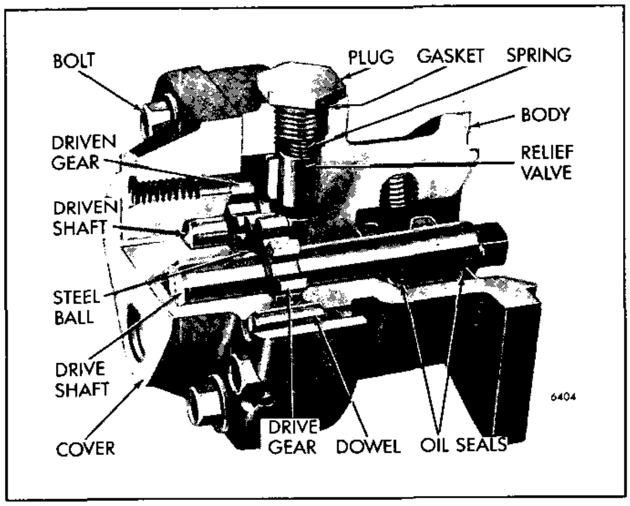


Fig. 1 – Typical Fuel Pump Assembly

The fuel pump body is recessed to provide running space for the pump gears (Fig. 2). Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the blower timing gear compartment (Fig. 3). A small hole "E" (Fig. 2) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

A higher temperature material lip type seal is now being used in the fuel pumps. The new fuel pump seal is made of a polyacrylate material, whereas the former seal is made of nitrile. The new fuel pumps (with the polyacrylate seals) will have the seals installed with the lips of the seals facing in the opposite direction of each other (Fig. 3). The former fuel pumps have the seals installed with both seal lips facing the mounting flange end of the pump. Both the polyacrylate and former nitrile seals are interchangeable in a fuel pump. Only the polyacrylate seals and fuel pumps with polyacrylate seals will be serviced.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

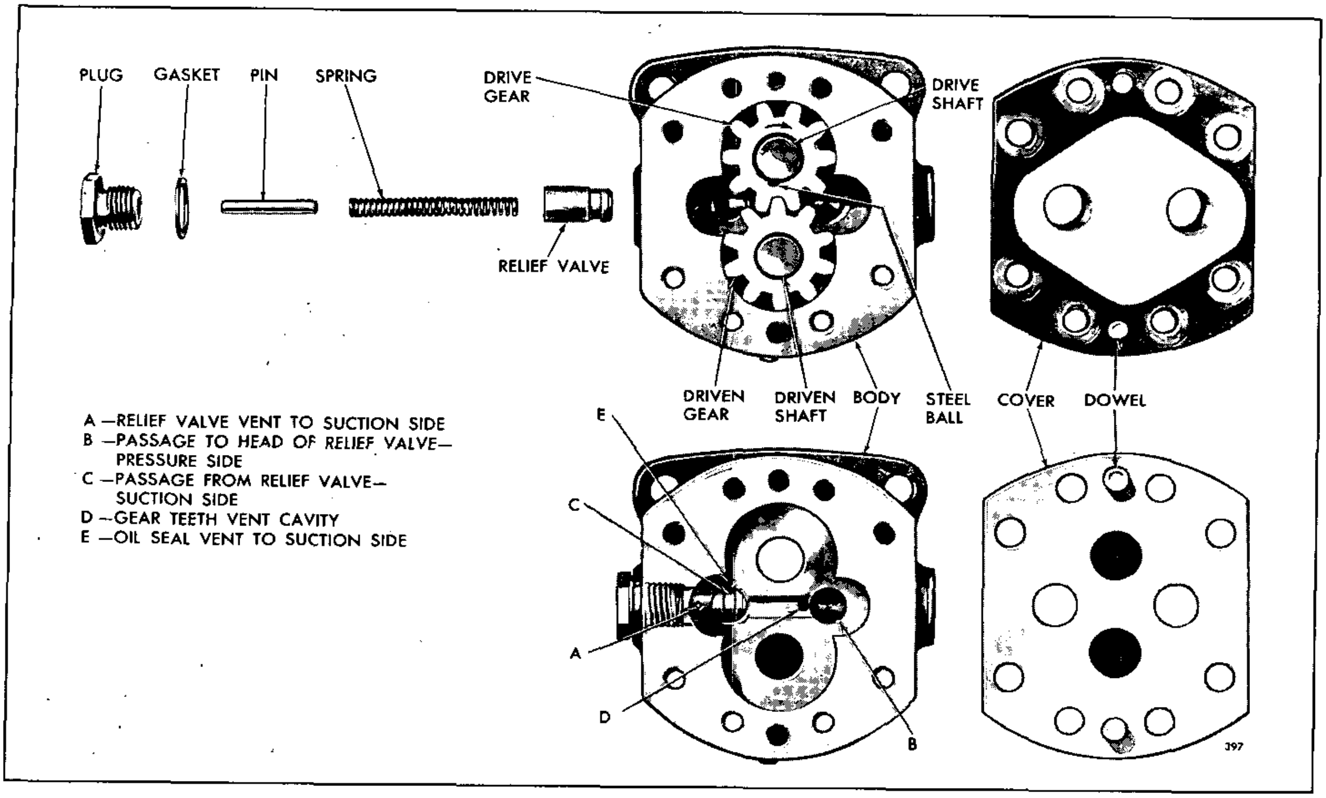


Fig. 2 – Fuel Pump Valving and Rotation (Right Hand Pump Shown)

The drive and driven gears are a line–to–line to a .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft.

A spring–loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 65 psi (448 kPa).

Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by by–passing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65 to 75 psi (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold (see Section 13.2).

Remove Fuel Pump

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
2. Disconnect the drain tube, if used, from the fuel pump.
3. Remove the three pump attaching bolts and withdraw the pump.
4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508–10 as shown in Fig. 4, refer to Figs. 1 and 6 and disassemble the pump as follows:

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.
2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.

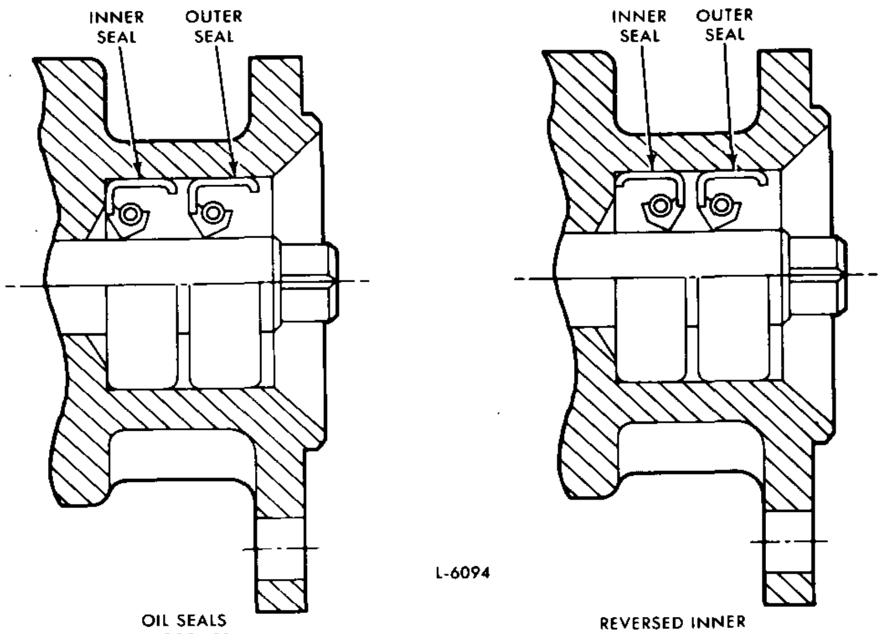


Fig. 3 – Fuel Pump Oil Seal Arrangements

3. Press the drive shaft just far enough to remove the steel locking ball. Then invert the shaft and gear assembly and press the shaft from the gear. *Do not misplace the steel ball.* Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.

4. Remove the driven shaft and gear as an assembly from the pump body. *Do not remove the gear from the shaft.* The driven gear and shaft are serviced only as an assembly.

5. Remove the relief valve plug and copper gasket.

6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.

7. If the oil seals need replacing, remove them with oil seal remover J 1508–13 (Fig. 5). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

NOTICE: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position (Fig. 3).

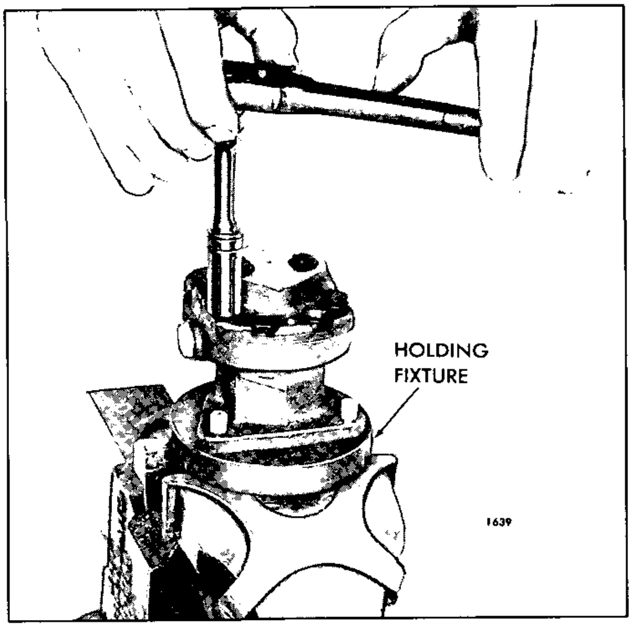


Fig. 4 – Removing Fuel Pump Cover

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also, check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Current standard fuel pumps (with 1/4" wide gears) incorporate a 1/8" shorter pump body with three drain holes, a 1/8" shorter drive shaft and a cover with a 3/8" inlet opening. When replacing a former pump, a 3/8" x 1/4" reducing bushing is required for the inlet opening and the unused drain holes must be plugged.

Assemble Fuel Pump

Refer to Figs. 1, 2, 3 and 6 and assemble the pump as follows:

1. *Lubricate the lips of the oil seals with a light coat of* vegetable shortening, then install the oil seal in the pump body as follows:

   a. Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will *face toward the shoulder on the tool.*

   When replacing the former nitrile fuel pump seals with the current polyacrylate seals, install them with the seal lips facing each other (Fig. 3).

   b. With the pump body supported on wood blocks (Fig. 7), insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange. Then drive the seal in until it *bottoms.*

   c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 8) until the shoulder of the adaptor contacts the pump body. Thus the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 18-22 lb-ft (24-30 N·m) torque.

3. Install the pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then place the ball in the detent and press the gear back until the end of the slot contacts the ball.

4. Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals as shown in Fig. 9.

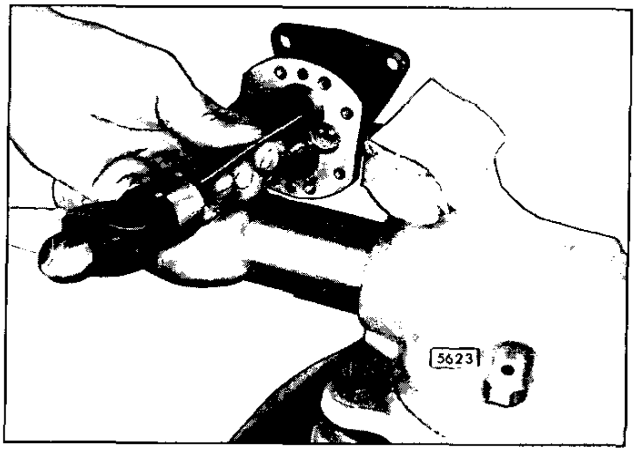


Fig. 5 – Removing Oil Seals Using Tool J 1508-13

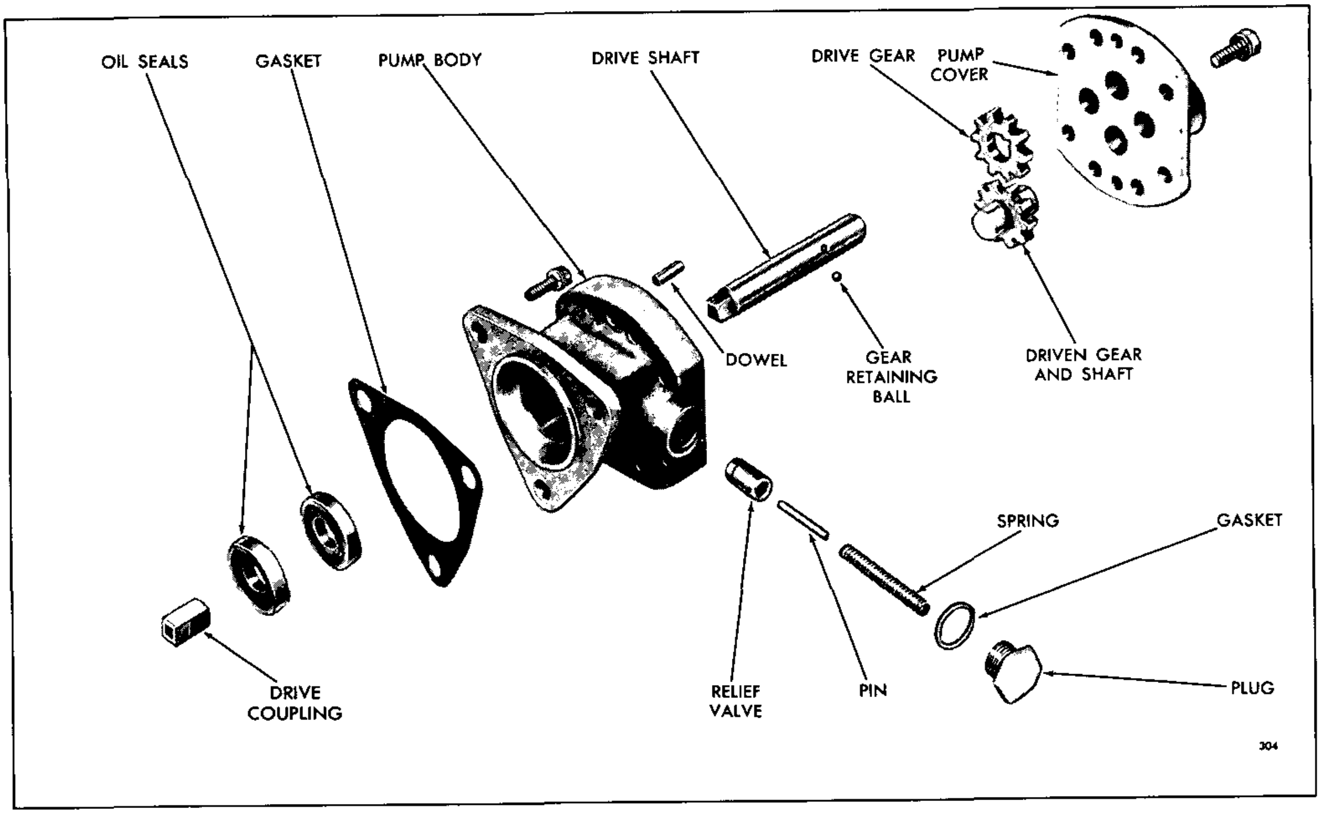


Fig. 6 – Fuel Pump Details and Relative Location of Parts (Right Hand Pump Shown)

5. Place the driven shaft and gear assembly in the pump body.

NOTICE: The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area.

Then place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

NOTICE: The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal–to–metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

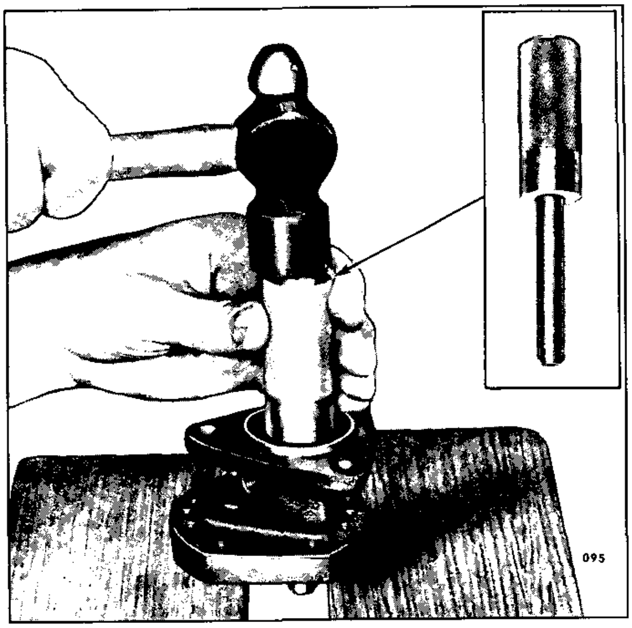


Fig. 7 – Installing Inner Oil Seal Using Tool J 1508–8

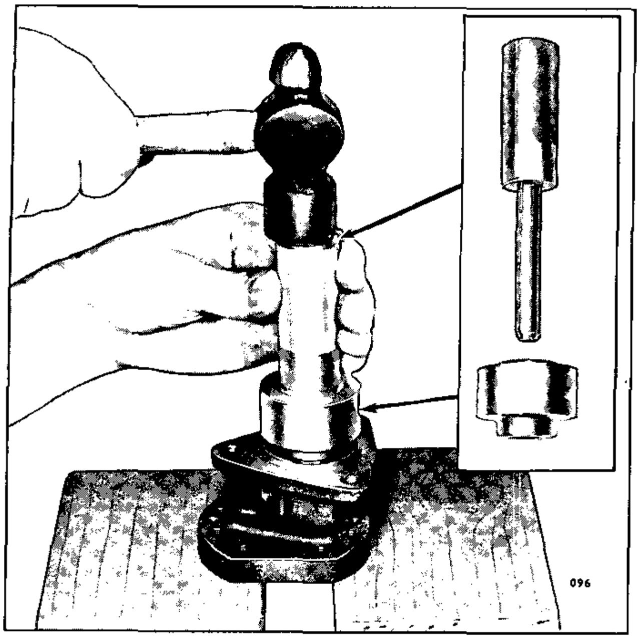


Fig. 8 – Installing Outer Oil Seal Using Tools J 1508-8 and J 1508-9

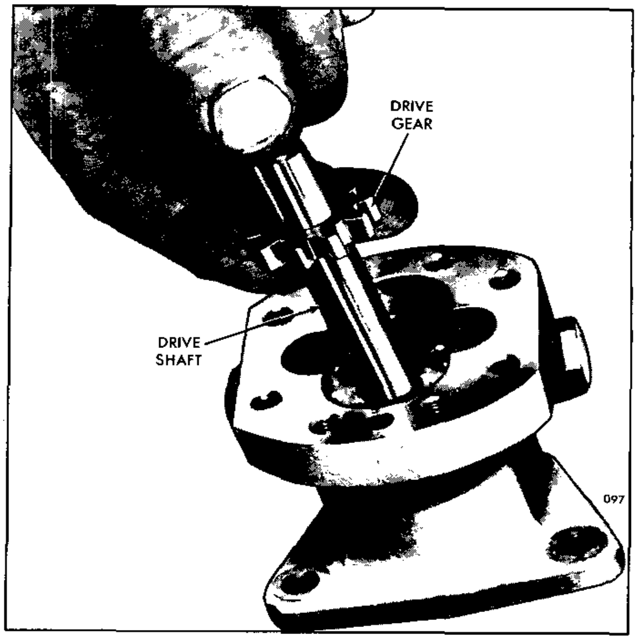


Fig. 9 – Installing Fuel Pump Drive Shaft and Gear Assembly

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.
9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.
10. Install 1/8" pipe plugs in the upper unused drain holes.
11. *If the pump is not to be installed immediately,* place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

1. Affix a new gasket to the pump body mounting flange and locate the pump drive coupling over the square end of the fuel pump drive shaft.
2. Install the fuel pump on the engine and secure it with *three nylon patch bolts.*

   To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.
3. If removed, install the inlet and outlet elbows in the pump cover. Before installing, coat the threads lightly with Gasoila, Permatex 2, or an equivalent non-hardening sealant.

- **NOTICE:** Do not use Teflon tape or paste on fittings, since this can result in fuel pump cover damage (cracking) before the required torque is reached.

- To prevent sealant from entering the fuel system, do not apply it to the first two (2) threads of the fittings. Tighten fittings to the low end of the torque. If necessary, continue tightening until alignment is achieved, but do not exceed maximum torque. Tighten fittings to the following values:

Fitting Size	Torque
1/4"	14–16 lb-ft. (19–22 N·m)
3/8"	18–22 lb-ft. (24–30 N·m)
1/2"	20–25 lb-ft. (27–34 N·m)

4. Connect the inlet and outlet fuel lines to the fuel pump.
5. Connect the fuel pump drain tube, if used, to the pump body.
6. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine using Primer J 5956. This will prevent the possibility of pump seizure upon initial starting.

FUEL PUMP DRIVE

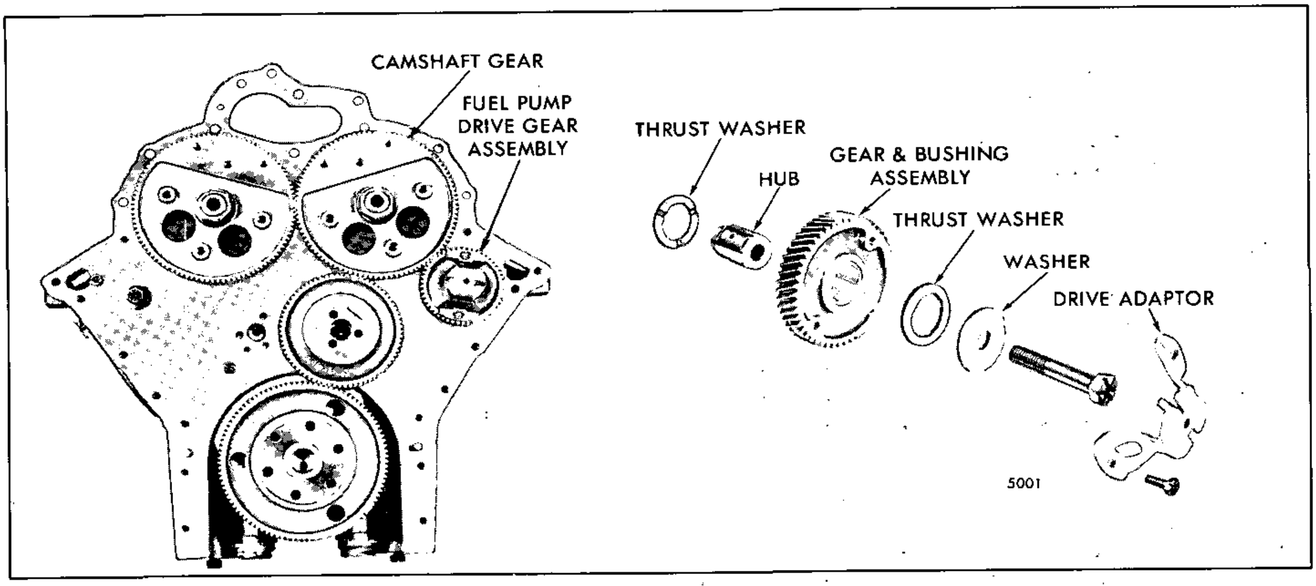


Fig. 1 – Typical Fuel Pump Drive Gear Mounting and Details (V–Type Engine)

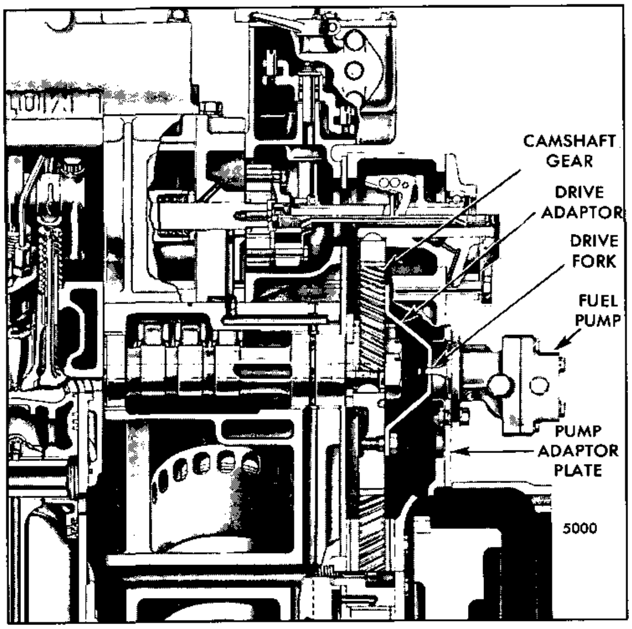


Fig. 2 – Camshaft Drive for Fuel Pump
(6V Engine Shown)

On some V–type engines, the fuel pump is mounted on the flywheel housing and is driven by an accessory drive gear. The fuel pump drive consists of a gear, stationary hub and drive adaptor (Fig. 1). The fuel pump drive gear rotates on the stationary hub attached to the cylinder block and is driven at approximately twice the engine speed by the camshaft gear. On other V–type engines, the fuel pump may be driven by either camshaft by means of a drive fork and drive adaptor (Fig. 2), in the same manner as the pump mounted on the flywheel housing of the In–line engines.

The fuel pump on In–line engines is driven by the governor weight shaft by means of a drive coupling. On some engines, the fuel pump is mounted on an adaptor plate attached to the flywheel housing. A drive adaptor attached to the balance shaft gear registers with a drive fork on the fuel pump shaft to provide a drive for the pump. Servicing of the fuel pump and drive on an In–line engine is covered in Section 2.2; the following applies only to a V–type engine.

To reduce the level of engine noise in the Series 53 engines, the pitch and pressure angle of the gear train and accessory drive gears has been changed. Refer to Section 1.7.1.

Lubrication

The fuel pump drive gear bearing (bushing type) is pressure lubricated. Lubricating oil from the oil gallery in the cylinder block flows through a drilled passage in the block, around the gear retaining bolt, and through another drilled hole in the gear hub to the bearing.

Remove Fuel Pump Drive Gear (V–Type Engine)

With the flywheel housing removed, remove the fuel pump drive gear as follows:

1. Remove the bolts and detach the fuel pump drive adaptor from the gear.
2. Loosen the fuel pump drive gear retaining bolt and remove the bolt and washer, gear, thrust washers and hub from the engine.

Inspection

Wash the drive gear and its related parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the thrust washers, hub and drive gear bearing for wear or scoring. Parts which are excessively worn or scored must be replaced. A pre–finished drive gear bearing (bushing type) is available for service. A new bushing should be pressed in flush to .010" below the gear face (both sides). Examine the gear teeth and, if they are excessively worn, scored or pitted, replace the gear and bushing assembly.

Install Fuel Pump Drive Gear (V–Type Engine)

Install the fuel pump drive gear and its related parts on the engine as outlined below:

1. Lubricate the drive gear bearing, thrust washers and hub with engine oil.
2. Assemble the fuel pump drive gear and thrust washers on the hub. The oil grooves in the thrust washers *must face toward the gear.* Note the position of the oil hole in the hub.

   Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in the excessive gear wear and may lead to serious engine damage.

   - **NOTICE:** The hardened gears are used on 6V turbocharged automotive engines. This change became effective with engine serial number 6D–229616.

3. Install the hub and gear assembly on the engine with the small diameter of the hub entering the rear end plate and the counterbore in the cylinder block, and the fuel pump drive gear teeth in mesh with the camshaft gear teeth. The oil hole in the hub should be toward the bottom of the engine.
4. Secure the gear and hub assembly in place with the gear retaining bolt and washer. Tighten the 1/2"–13 bolt to 71–75 lb–ft (96–102 N·m) torque.
5. Check the clearance between the gear and the thrust washer. The specified clearance between new parts is between .005" and .018". The maximum clearance between used parts must not exceed .022".
6. Attach the fuel pump drive adaptor to the gear with the two bolts.

FUEL STRAINER AND FUEL FILTER

(BOLT-ON TYPE)

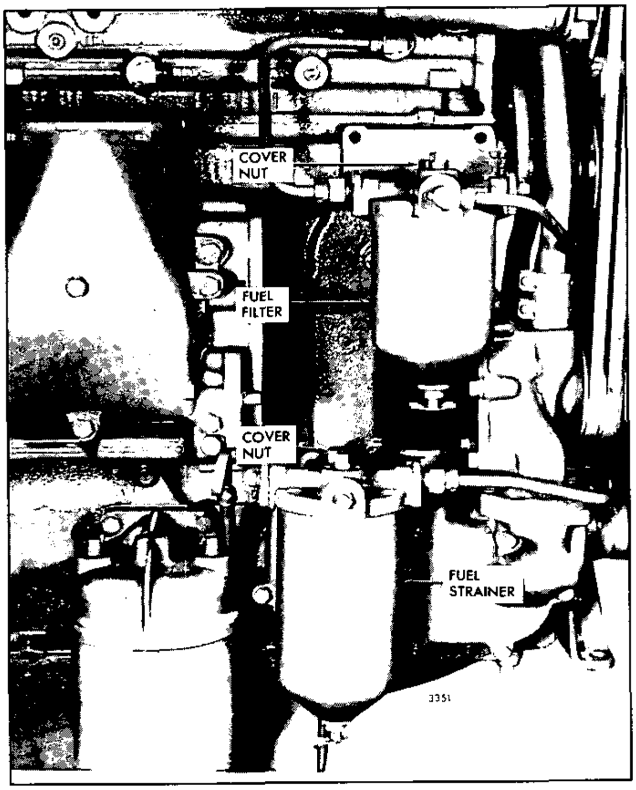


Fig. 1 – Typical Fuel Strainer and Fuel Filter Mounting

- A fuel strainer (primary) and fuel filter (secondary), Fig. 1, are used to remove impurities from the fuel. The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density–type element is capable of filtering out particles of 30 microns (a micron is approximately .00004"). The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper–type (cellulose) element (Fig. 2) can remove particles as small as 10 microns. Fiberglass elements can remove particles as small as 5 microns.

NOTICE: A fuel tank of galvanized steel should never be used for fuel storage, as the fuel oil reacts chemically with the zinc coating to form powdery flakes which quickly clog the fuel filter and cause damage to the fuel pump and the fuel injectors.

The fuel strainer and fuel filter are essentially the same in construction and operation, and they will be treated as one in this section.

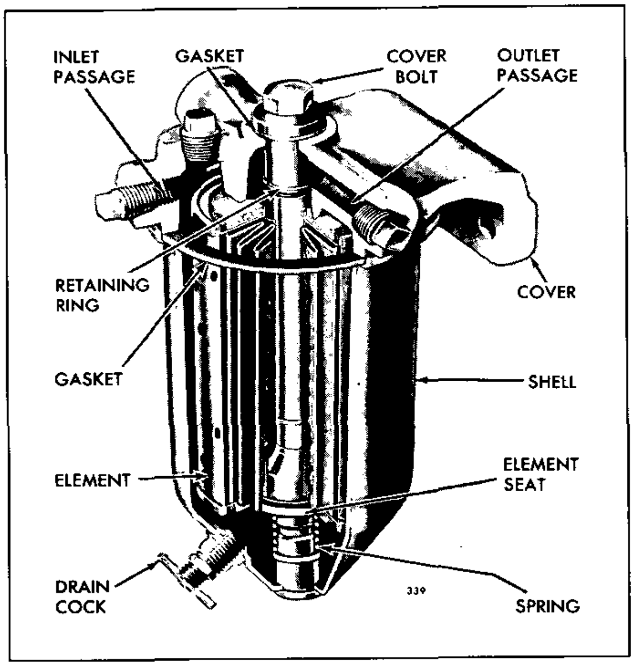


Fig. 2 – Fuel Filter Assembly

The filter and strainer, illustrated in Figs. 3 and 4, consist basically of a shell, a cover, and a replaceable filtering element. The assembly is made oil tight by a shell gasket, a cover nut or bolt, and a cover nut or bolt gasket.

The central stud is a permanent part of the shell and, when the unit is assembled, extends up through the cover where the nut or bolt holds the assembly together.

A filter element sets over the central stud inside the shell and is centered in the shell by the stud.

The former and current cover assemblies are visibly different. The cast letter "P" (primary) has been added to the top of the strainer cover and the letter "S" (secondary) has been added to the top of the filter cover.

Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the

interior of the filter element, up through the central passage in the cover and into the outlet passage, then to the fuel inlet manifold in the cylinder head.

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to *Troubleshooting* in Section 15.2 for corrective measures.

Replace Fuel Strainer Or Filter Element

The procedure for replacing an element is the same for the fuel strainer or fuel filter. Refer to Figs. 3 and 4 and replace the element as follows:

NOTICE: Only filter elements designed for fuel oil filtration should be used to filter the fuel.

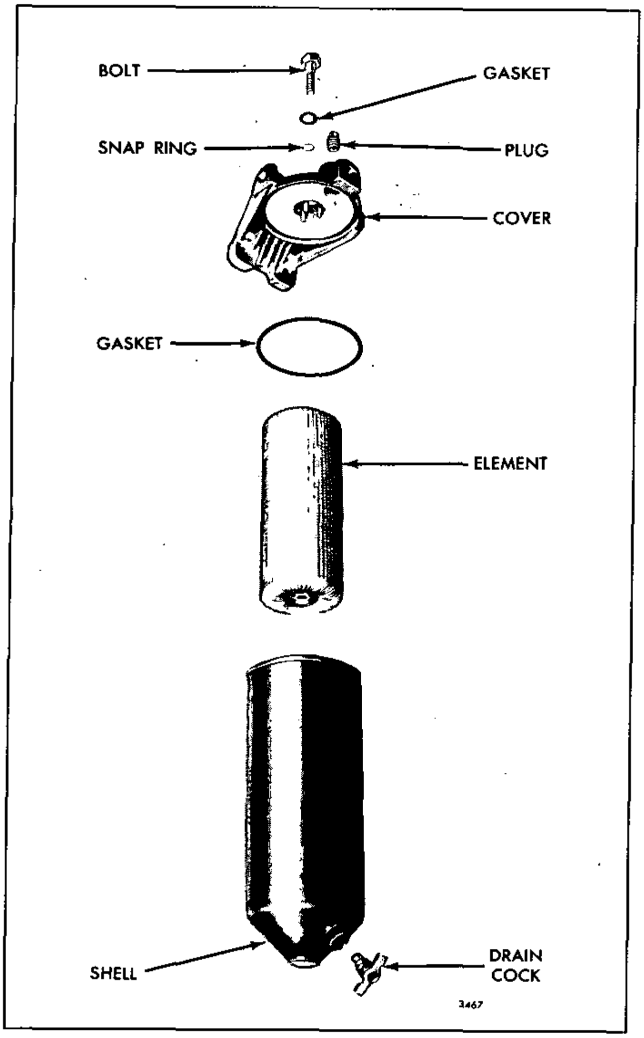


Fig. 3 – Fuel Strainer Details and Relative Location of Parts

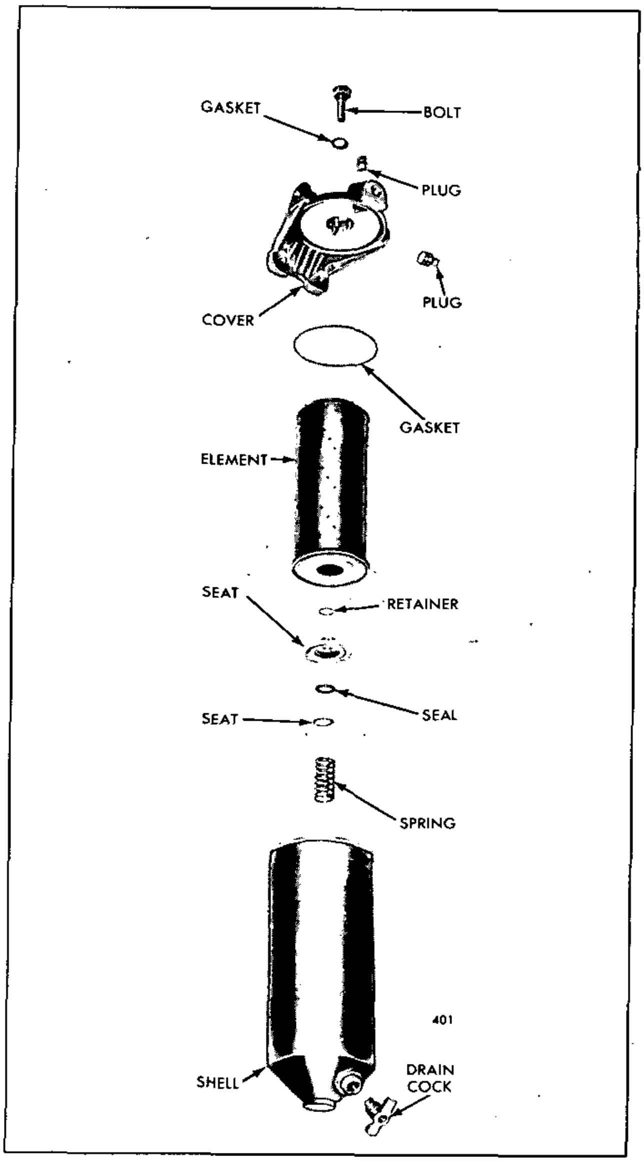


Fig. 4 – Fuel Filter Details and Relative Location of Parts

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover nut or bolt just enough to allow the fuel oil to drain out freely. Then close the drain cock.

   NOTICE: The wiring harness, starting motor or other electrical equipment must be shielded during the filter change, since fuel oil can permanently damage the electrical insulation.

2. While supporting the shell, unscrew the cover nut or bolt and remove the shell and element. Also remove and discard the cover nut retaining ring, if used.

3. Remove and discard the filter element and shell gasket, the cover nut or bolt gasket, and, if used, the cover bolt snap ring.

   Current strainers and filters do not incorporate the cover bolt snap ring. This was eliminated to facilitate replacement of the bolt gasket with each element replacement.

4. Wash the shell thoroughly with clean fuel oil and dry it with compressed air.

   CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

5. Examine the element seat and the retaining ring to make sure they have not slipped out of place. Check the spring by pressing on the element seat. When released, the seat must return against the retaining ring.

   The element seat, spring, washer and seal can not be removed from the strainer shell. If necessary, the shell assembly must be replaced. However, the components of the filter shell are serviced. Examine the filter retainer seal for cracks or hardening. If necessary, replace the seal.

   The current strainer and filter elements include the element, the cover gasket and cover bolt gasket. The strainer element also includes both the former and current bolt gaskets.

6. Place a new element over the center stud and push it down against the element seat. Make sure the drain cock is closed, then fill the shell about two–thirds full with clean fuel oil.

   Thoroughly soak the density–type *strainer* element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

7. Place a new shell gasket in the recess of the shell; also place a new gasket on the cover nut or bolt.

8. Place the shell and element in position under the cover. Then thread the cover bolt (or nut) in the center stud.

9. With the shell and the gasket properly positioned, tighten the cover bolt or nut just enough to prevent fuel leakage.

10. Remove the pipe plug at the top of the cover and complete filling of the shell with fuel. Fuel system primer J 5956 may be used to prime the entire fuel system.

11. Start the engine and check the fuel system for leaks.

FUEL STRAINER AND FUEL FILTER

(SPIN–ON TYPE)

A spin–on type fuel strainer and fuel filter (Fig. 5) is used on certain engines. The spin–on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly (Fig. 6). No separate springs or seats are required to support the filters.

• Replaceable paper type (cellulose) elements can remove particles as small as 10 microns. Fiberglass elements can remove particles as small as 5 microns.

The filter covers incorporate a threaded sleeve to accept the spin–on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin–on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

Filter Replacement

A 1″ diameter twelve–point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.
2. Fill a new filter replacement cartridge about two–thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.
3. Install the new filter assembly and tighten it to one–half of a turn beyond gasket contact.

Fig. 5 – Typical Spin–On Filter Mounting

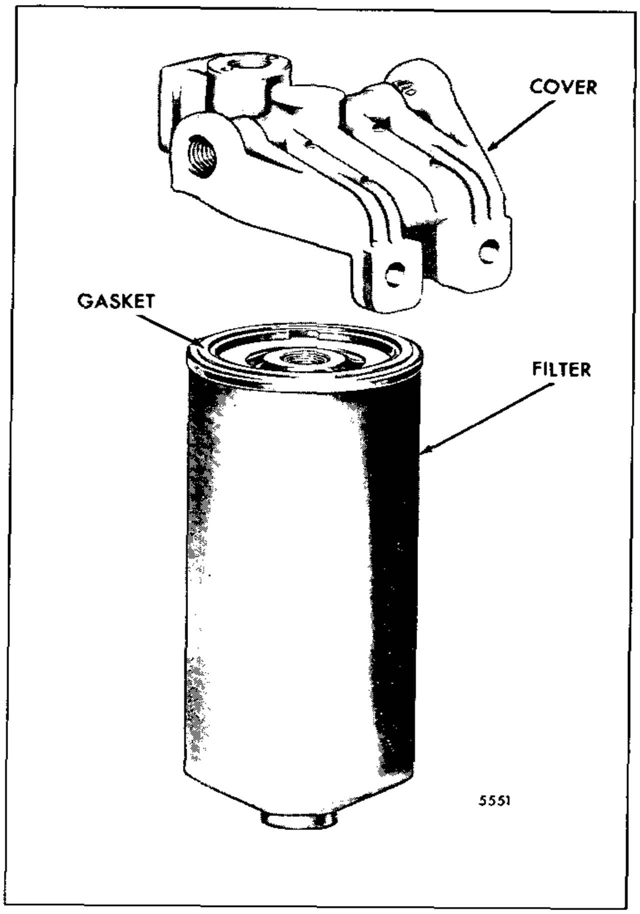


Fig. 6 – Spin–On Filter Details

FUEL COOLER (V Engines)

A fuel cooler may be mounted in the raw water system, between the heat exchanger and the raw water pump, so that the fuel leaving the engine is cooled before it returns to the fuel tank.

Fuel continually cycling through an engine causes the fuel in the tank to become heated after extended operation. Excessive fuel temperatures can affect engine operation. An increase in the fuel inlet temperature above 90°F (32°C) will result in a brake horsepower loss of approximately 2% per 20°F (11°C) increment fuel temperature increase.

Remove Fuel Cooler

1. Disconnect the flexible hoses at the fuel cooler.

2. Loosen the hose clamps and slide the hoses back on the raw water pump tubes.

Clean Fuel Cooler

Clean the oil side of the cooler core first, then immerse it in the following solution: Add 1/2 pound of oxalic acid to each 2–1/2 gallons (9.5 liters) of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming.

Watch the process carefully. When bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

Pressure Test Fuel Cooler

After the fuel cooler has been cleaned, check it for leaks by plugging one of the fuel openings with a 1/4" pipe plug and attaching an air hose to the other opening. Apply approximately 100 psi (689 kPa) air pressure and submerge the cooler in a container of heated water (180°F or 82°C). A leak will be indicated by air bubbles in the water. If leaks are indicated, replace the cooler.

- **CAUTION: To avoid personal injury when making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of the cooler core.**

Install Fuel Cooler

Reverse the procedure for removing the fuel cooler.

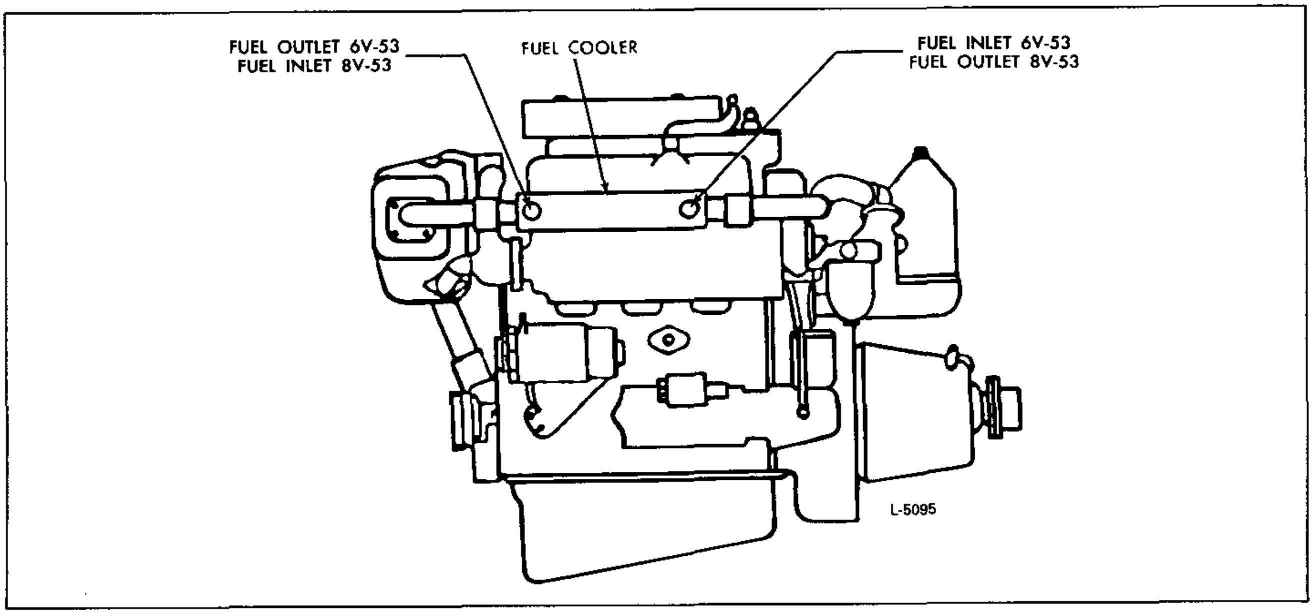


Fig. 1 – Fuel Cooler Mounting (V Engines)

MECHANICAL GOVERNORS

Horsepower requirements on an engine may vary due to fluctuating loads. Therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors. The following types of mechanical governors are used:

1. Limiting Speed Mechanical Governor.
2. Variable Speed Mechanical Governor.

Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with a limiting speed mechanical governor.

Engines subjected to varying load conditions that require an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator, are equipped with a variable speed mechanical governor. However, a variable speed governor cannot be used on an engine equipped with an Allison vehicle transmission. Each type of governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and drive ratio. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to the valve rocker cover.

Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine. However, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, check the engine as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.
2. Check the engine to be sure that all of the cylinders are firing properly (refer to Section 15.2). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in Section 2.1 or 2.1.1.
3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector hold–down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20–25 lb–ft (27–34 N·m) torque.
2. An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in Section 2.1 or 2.1.1.
3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Section 14.
4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no–fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in Section 14.
5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.
6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

LIMITING SPEED MECHANICAL GOVERNOR

In-Line Engine

The limiting speed mechanical governor performs the following functions (Fig. 1):

1. Controls the engine idle speed.
2. Limits the maximum operating speed of the engine.

The mechanical engine governors are identified by a name plate attached to the governor housing. The letters D.W.–L.S. stamped on the name plate denote a double–weight limiting speed governor.

The governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

Operation

The governor holds the injector racks in the advanced fuel position for starting when the throttle control lever is in the idle position. Immediately after starting, the governor moves the injector racks to the position required for idling.

The centrifugal force of the revolving governor low and high speed weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever operates against the high and low speed springs through the spring cap, while the other end provides a moving fulcrum on which the differential lever pivots.

When the centrifugal force of the revolving governor weights balances out the tension on the high or low speed spring (depending on the speed range), the governor stabilizes the engine speed for a given setting of the speed control lever.

In the low speed range, the centrifugal force of the low and high speed weights together operate against the low speed spring. As the engine speed increases, the centrifugal force of the low and high speed weights together compresses the low speed spring until the low speed weights are against their stops, thus limiting their travel, at which time the low speed spring is fully compressed and the low speed spring cap is within .0015" of the high speed spring plunger.

Throughout the intermediate speed range the operator has complete control of the engine because the low speed gap is closed and the low speed weights are against their stops, and the high speed weights are not exerting enough force to overcome the high speed spring. As the speed continues to increase, the centrifugal force of the high speed weights increases until this force can overcome the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

A fuel rod, connected to the differential lever and the injector control tube lever, provides a means for the governor to change the fuel settings of the injector rack control levers.

The engine idle speed is determined by the force exerted by the governor low speed spring. When the governor speed control lever is placed in the idle position, the engine will operate at the speed where the force exerted by the governor low speed weights will equal the force exerted by the governor low speed spring.

Adjustment of the engine idle speed is accomplished by changing the force on the low speed spring by means of the idle speed adjusting screw. Refer to the tune–up section for idle speed adjustment.

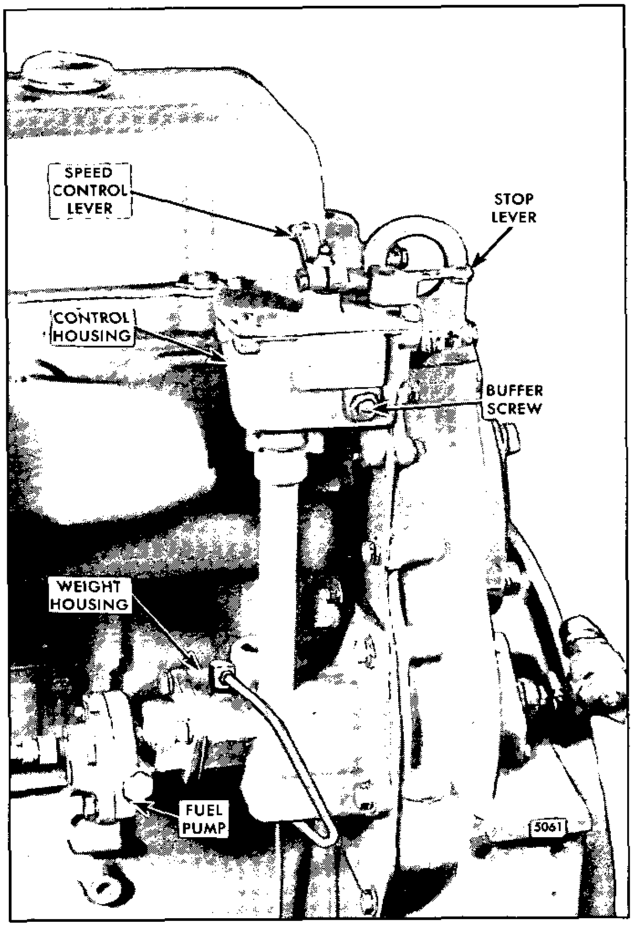


Fig. 1 – Governor Mounting

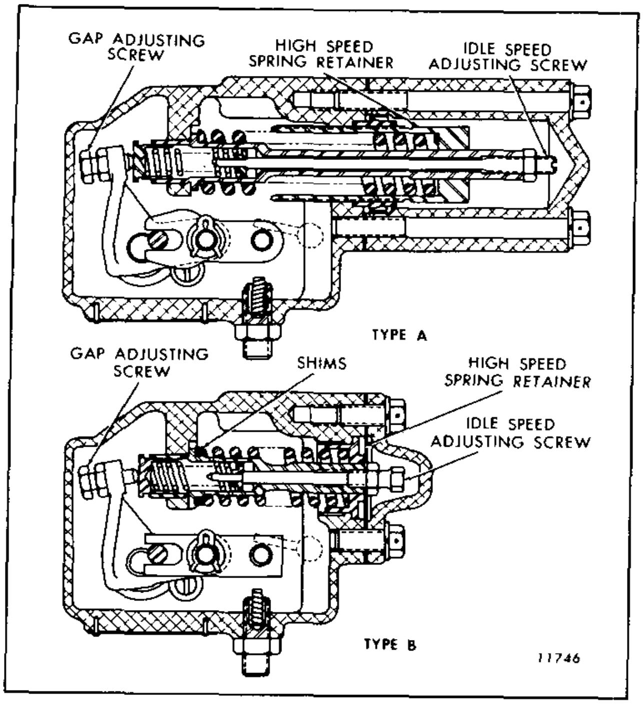


Fig. 2 – Differences Between Industrial and Vehicle Type Governor Assemblies

The engine maximum no–load speed is determined by the force exerted by the high speed spring. When the throttle control lever is placed in the maximum speed position, the engine will operate at a speed where the force exerted by the governor high speed weights will equal the force exerted by the governor high speed spring.

Adjustment of the maximum no–load speed is accomplished by changing the tension on the high speed spring. Refer to the tune–up section for the maximum no–load speed adjustment.

Lubrication

The governor is lubricated by oil splash from the engine gear train and by a pressure line on current engine models. The oil passes through the governor weight housing on to the shaft and weight assemblies. The oil is distributed to the various moving parts within the governor by the revolving weights. Surplus oil drains from the governor through holes in the governor bearing retainer back to the engine gear train.

Remove Governor from Engine

Before removing the governor from the engine, the operation should be checked as outlined in Section 2.7. If the governor fails to control the engine properly after performing these checks, remove and recondition it.

1. Disconnect the linkage to the governor control levers.
2. Remove the governor cover and gasket.
3. Detach the spring housing from the governor housing by removing the two bolts and lock washers.
4. Loosen the high speed spring retainer locknut with spanner wrench J 5895 and remove the spring assembly (Fig. 2).
5. Loosen the fuel rod cover hose clamps.
6. Clean and remove the rocker cover from the cylinder head.
7. Disconnect the fuel rod from the injector control tube lever. Remove the clip that holds the fuel rod to the differential lever and lift the fuel rod from the lever.
8. Detach the fuel pump by disconnecting the fuel lines and removing the three bolts. Also, disconnect the lubricating oil line, if used.
9. Remove the five bolts from the governor weight housing and the two bolts from the governor control housing.
10. Detach the governor and gasket from the engine.

Disassemble Governor Cover

1. Remove the return spring and clip from a single lever cover only, then loosen the governor speed control lever retaining bolt and lift the control lever from the speed control shaft (Fig. 3).
2. Remove the retaining ring and washer. Withdraw the speed control shaft from the cover.
3. Remove the seal ring from the cover. The single lever cover has the seal ring at the top of the cover. The double lever cover has the seal ring at the bottom of the cover.
4. Loosen the governor stop lever retaining bolt and lift the lever from the stop lever shaft.
5. Remove the retaining ring and washers and withdraw the stop lever shaft from the cover.
6. Remove the seal ring from the top of the cover.

Disassemble Governor Weight Housing

1. Remove the gear retaining nut from the shaft, then remove the gear, key and spacer from the shaft.
2. Remove the small screw holding the bearing retainer in place.
3. Turn the bearing support until the large opening is centered over the fork on the operating shaft.

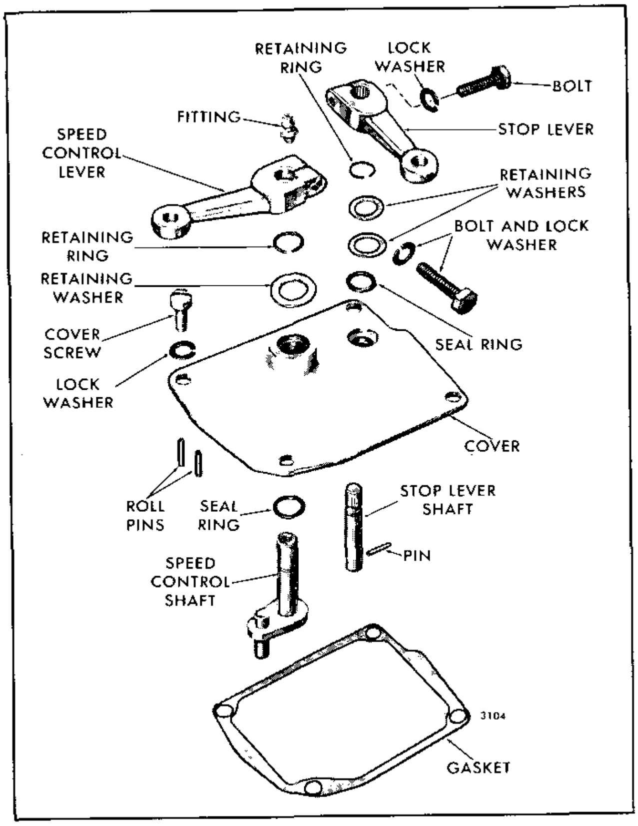


Fig.3 – Governor Cover Details and Relative Location of Parts

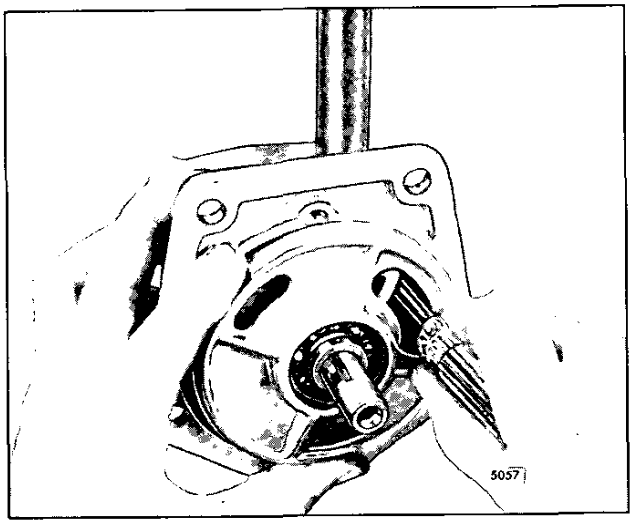


Fig. 4 – Removing Fork from Operating Shaft

4. Lift up on the weight shaft until there is enough clearance for a 5/16" socket wrench to be placed on the screws that hold the fork to the operating shaft (Fig. 4). Then remove the two screws and washers.

5. Lift the shaft and weight assembly out of the governor weight housing.

6. Remove the screw and washers holding the bearing in the control housing and lift the shaft assembly out of the housing.

7. Place a rod approximately 18" long through the control housing and knock the plug out of the bottom of the weight housing.

8. Remove the snap ring and press the bearing from the weight housing.

9. Remove the spring clip and washer from the governor operating shaft lever and remove the governor differential lever.

10. Press the bearing and operating shaft lever from the operating shaft, if necessary.

11. If necessary, disassemble the control housing from the weight housing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer from the weight shaft.

2. If necessary, remove the snap ring and press the bearing from the bearing retainer.

3. Remove the weight pin retainers from the governor weight pins, then drive the pins out of the carrier and weights. *Drive the pins out of the carrier from the weight pin retainer end.*

   Remove the governor weights. Punch mark the carrier at the retainer end of the weight pins so the pins may be placed in the proper position when reinstalling the weights in the carrier.

4. Slide the riser and bearing assembly from the shaft. Do not disassemble the bearing since the riser and bearing are serviced only as an assembly.

Inspection

Immerse all of the governor parts in a suitable cleaning fluid to loosen and remove all foreign material. Use a bristle brush and compressed air as necessary to ensure cleanliness of all parts.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil; then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots. Replace the bearings if rough or tight spots are detected.

The lower governor drive components have been revised to reduce the clearance between the riser and the

weight shaft. With this change, additional lubrication is provided to the governor by an oil line connected between the oil gallery in the cylinder block and the governor weight housing. When replacing the riser assembly, shaft and carrier assemblly, or the complete governor assembly, the new oil line must be installed to provide adequate lubrication.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and bearing assembly. Examine the weight carrier pins for wear and replace them if necessary.

Inspect the weight carrier, weights and retaining pins for wear. The current single–weight carrier replaces the former double–weight carrier.

Inspect the fuel pump drive end of the weight shaft. Replace the shaft if the end is worn or rounded.

Inspect the bushing in the weight housing. Replace the bushing if it is worn excessively.

Inspect the spring seats, plungers, adjusting screws, lock nuts and other parts of the control housing for defects that might affect governor operation.

Assemble Governor Cover

New mechanical governor cover assemblies with serrated shafts are being used on In–line 53 engines.

The limiting speed governor cover assemblies include a new, longer 7/16" diameter speed control shaft and a new 3/8" diameter serrated stop lever shaft (Fig. 3). The serrations on the shafts ensure positive clamping between the serrated levers and the shafts and prevent any slippage. Four serrations on the stop lever shaft of the limiting speed governor are eliminated. This allows certain customers to design a mating lever with missing serrations which will provide a *fixed position* for particular requirements. Levers with missing serrations are not provided. The former and new cover and shaft assemblies are interchangeable on a governor, and only the new assemblies will be serviced. Since the new serrated shafts can be used with the former covers, only the new serrated shafts will be serviced.

1. Place a new seal ring in the counterbore of the cover (Fig. 2). The single lever cover has the seal ring at the top of the cover. The double lever cover has the seal ring at the bottom of the cover.
2. Lubricate the speed control shaft with engine oil, then slide the shaft through the cover. Install the washer and retaining ring on the shaft.
3. Place the speed control lever over the shaft and secure it with the bolt and lock washer.
4. On double lever covers, lubricate the stop lever shaft with engine oil, then slide the shaft through the cover.
5. Place the seal ring in the counterbore of the shaft opening, then install the washers over the shaft. Lock the shaft in place with the retaining ring.
6. Place the stop lever on the shaft and secure it with the bolt and lock washer.

Assemble Control Housing

1. Install a 1/8" pipe plug in the tapped hole in the side of the control housing.
2. If necessary, assemble the control housing to the weight housing, using a good quality sealant between the tube and the housings.
3. Install the governor operating shaft lower bearing, numbered side out, in the weight housing. Install the snap ring to secure the bearing (Fig. 5).
4. Apply a quality sealant around the edge of a new plug and tap it in place.
5. Start the governor operating shaft upper bearing over the upper end of the operating shaft. Support the lower end of the shaft on the bed of an arbor press. Use a sleeve and press down on the inner race of the bearing until it contacts the shoulder of the operating shaft.
6. Place the operating lever on the shaft with the flat surface on the shaft registering with the flat surface on the lever. Press the lever tight against the bearing on the shaft.
7. Lubricate both bearings with engine lubricating oil. Insert the lever and operating shaft assembly in the control housing. Guide the lower end into the bearing.
8. Secure the upper operating shaft bearing with the round head retaining screw and washers.
9. Place the fork on the operating shaft with the two cam faces facing the fuel pump.
10. Secure the fork to the operating shaft with two screws and lock washers.
11. Place the differential lever over the operating shaft lever pin and secure it in place with a washer and spring pin.

Assemble Governor Weight and Shaft Assembly

1. If the carrier was removed from the weight shaft, press the carrier on the shaft so as to allow a clearance of .001" to .006" between the shaft shoulder and the rear face of the carrier.
2. Press the governor weight shaft bearing into the bearing retainer by pressing on the outer race of the bearing (Fig. 6).

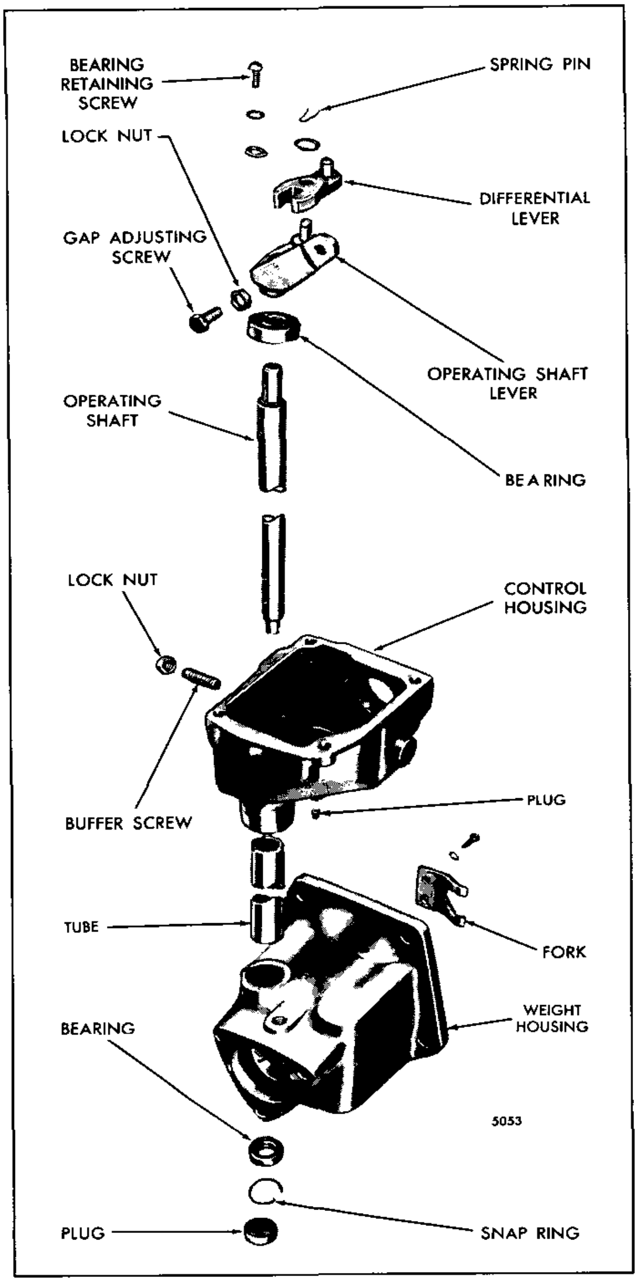


Fig. 5 – Governor Housings and Relative Location of Parts

3. Install the snap ring in the retainer with the flat side of the ring facing the bearing.

4. Press the bearing retainer on the weight shaft until the bearing is against the shoulder on the shaft.

NOTICE: To prevent any damage, press only on the inner race of the bearing.

5. Place the riser on the weight shaft.

6. Position the low speed weights, identified by the short cam arm and three center laminations, each approximately 9/64" thick, on the weight carrier. Drive the weight pins in place and install the weight pin retainers.

7. Install the high speed weights in the same way. The high speed weights are identified by the long cam arm and three center laminations; the middle lamination is 3/16" thick and the outer ones are 1/8" thick.

   The weight pins must be reinstalled in the same positions from which they were removed.

8. Slide the shaft and weight assembly into the weight housing with the riser bearing placed behind the fork.

9. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Tighten the two screws holding the fork to the operating shaft with a 5/16" socket wrench.

10. Turn the bearing retainer until the counterbored hole in the retainer and housing line up. Install the screw to secure the bearing retainer to the weight housing.

11. Place the drive gear spacer on the shaft. Install the key in the keyway and place the gear on the shaft.

12. Tap the gear until the spacer is against the bearing. Install the drive gear retaining nut and tighten it to 125–135 lb-ft (170–183 N·m) torque.

13. Check the backlash between the governor drive gear and the camshaft or balance shaft gear. The backlash should be .0030" to .0050" between new gears and should not exceed .0070" between used gears. If necessary, loosen and readjust the rear end plate to bring gear lash within specifications.

Install Governor

Refer to Fig. 1 and install the governor on the engine as follows:

1. Attach the fuel rod to the differential lever and secure it in place with a washer and spring pin.

2. Attach a new gasket to the governor weight housing.

3. Insert the end of the fuel rod through the hose and clamps and into the opening in the cylinder head and position the governor weight housing against the engine rear end plate; the teeth on the governor drive gear must mesh with the teeth on the camshaft gear or balance shaft gear. Refer to Section 1.0 for allowable backlash.

4. Install the three 12-point head bolts with copper washers in the governor weight housing next to the

cylinder block. Install the two remaining bolts with steel washers and lock washers. Tighten the bolts to 35 lb–ft (47 N·m) torque.

5. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 10–12 lb–ft (14–16 N·m) torque.

6. On current engines, install the lubricating oil line and fittings to the weight housing and the cylinder block.

7. Align and tighten the hose clamps on the fuel rod covers.

8. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

9. Assemble the industrial governor spring mechanism as follows:

   a. Thread the spring retainer locknut on the retainer.

   b. Thread the idle speed adjusting screw on the governor spring plunger.

   c. *Place the high speed spring over the governor* spring plunger.

   d. Lubricate and install the spring plunger assembly in the spring retainer and secure it with a locknut so that approximately 1/4" of the idle *speed adjusting screw extends beyond the nut.*

   e. Lubricate and insert the spring seat, low speed spring and the spring cap in the open end of the spring plunger.

10. Thread the spring retainer and spring assembly into the governor housing and tighten the locknut finger tight until an engine tune–up is performed.

11. Assemble the vehicle governor spring mechanism as follows:

   a. Back off the locknut at the outer end of the adjusting screw to within 1/16" of the slotted end of the screw.

   b. Slip the shims, if used, and the high speed spring over the plunger. Position the retainer over the high speed spring and insert the adjusting screw into the plunger.

   c. Position the seat and cap on the ends of the low speed spring and insert the assembly into the hollow end of the plunger.

   d. Insert the spring and plunger assembly into the control housing and tighten the retainer nut with spanner wrench J 5895.

12. Thread the spring retainer and spring assembly into the governor; the locknut should be finger tight until an engine tune–up is performed.

13. Use a new gasket when installing the governor cover and lever assembly. Be sure the speed control shaft pin engages the slot in the differential lever and the stop lever is in the correct position. Secure the cover with four screws and lock washers.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

14. Install the return spring and spring clip (single lever cover only).

15. Add all purpose grease to the speed control shaft through the grease fitting on top of the shaft. *At temperatures above 30°F (1°C) use a No. 2 grade grease and a No. 1 grade grease below this temperature.*

16. Connect the linkage to the governor control levers.

17. Install the fuel pump and fuel lines.

18. Perform an engine tune–up as outlined in Section 14.

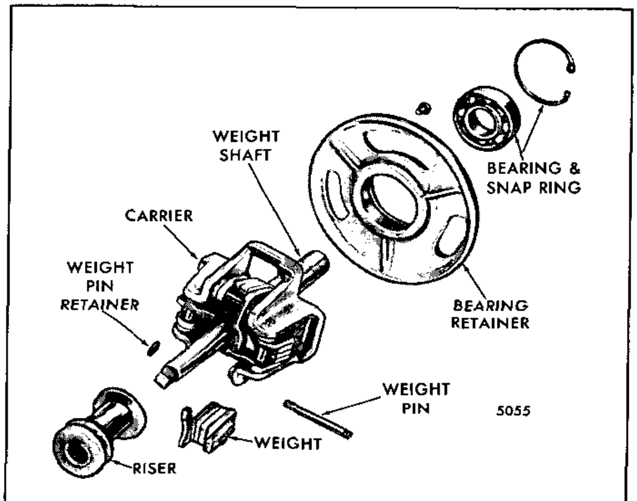


Fig. 6 – Governor Weight Details and Relative Location of Parts

LIMITING SPEED MECHANICAL GOVERNOR

6V Engine

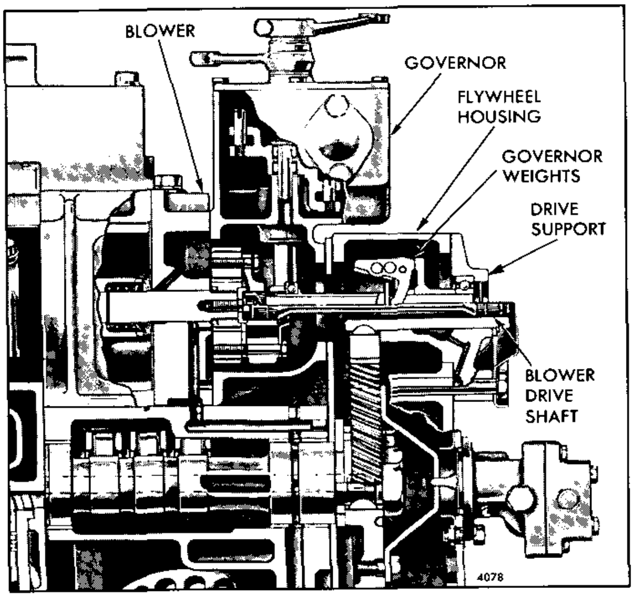


Fig. 1 – Limiting Speed Governor and Drive on 6V–53 Engine

The limiting speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idle speed.
2. Limits the maximum operating speed of the engine.

The double–weight governor, identified by the letters D.W.–L.S. stamped on the governor name plate, is mounted between the engine blower and the flywheel housing (Fig. 2). One end of the governor weight shaft is splined to a drive plate attached to the driven blower timing gear to provide a means of driving the governor. The other end of the shaft is supported by a bearing in the blower drive support (Fig. 1).

The governor consists of four basic subassemblies: a cover and lever assembly, governor housing, spring housing, and a weight and shaft assembly.

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In the RUN position, the stop lever holds the fuel injector racks near the *full–fuel* position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

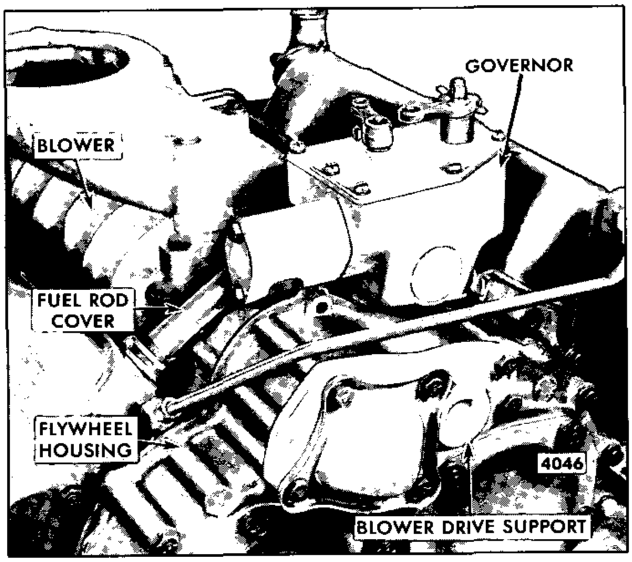


Fig. 2 – Governor Mounting on 6V–53 Engine

Current governor covers include a longer serrated shutdown shaft and lever to provide positive clamping between the serrated levers and shafts. The longer shaft also has provisions for a yieldable speed control lever.

To limit fuel input during engine start–up, when the speed control lever is in its idle position, the turbocharged engines use a starting aid screw (Fig. 7).

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever bears against the governor spring cap while the other end provides a moving fulcrum on which the differential lever pivots.

In the low speed range, the centrifugal force of the low speed weights and the high speed weights operates against the low speed spring. As the engine speed increases, the centrifugal force of both pairs of weights compresses the low speed spring until the low speed weights have reached the limit of their travel, at which time the low speed spring is fully compressed and the spring cap is within .0015″ of the high speed spring plunger.

Throughout the intermediate speed range, the operator has complete control of the engine because both the low speed spring and the low speed weights are against their stops, and the high speed weights are not exerting enough force to overcome the high speed spring.

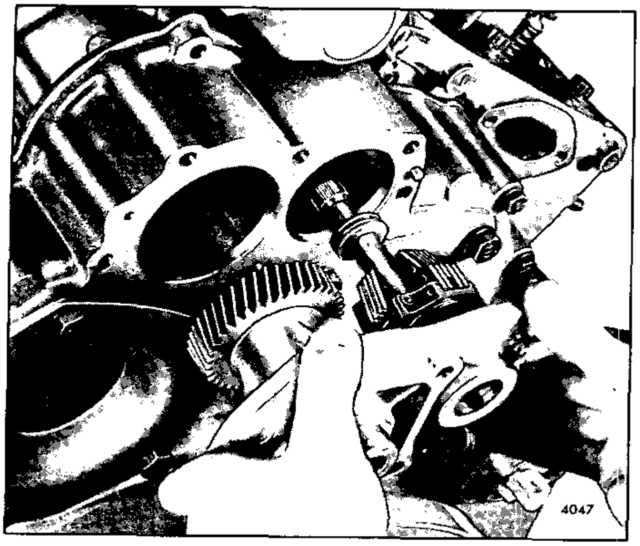


Fig. 3 – Removing or Installing Blower Drive Support

As the engine speed continues to increase, the centrifugal force of the high speed weights increases until this force overcomes the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the differential lever and the injector control tube levers through the control link lever. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no–fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.

Lubrication

The governor is lubricated by a spray of pressurized lubricating oil from the blower rear end plate to the blower timing gears which distribute this oil to various parts of the governor. Oil splash from the gear train provides lubrication for the governor weights and shaft. Excess oil overflows into the gear train compartment and returns to the crankcase.

Remove Governor From Engine

Check the governor as outlined in Section 2.7 and, if it fails to control the engine properly, remove and disassemble it for further inspection.

Since the governor is mounted between the blower and the flywheel housing, the blower and blower drive support assemblies must also be removed. Remove the governor as follows:

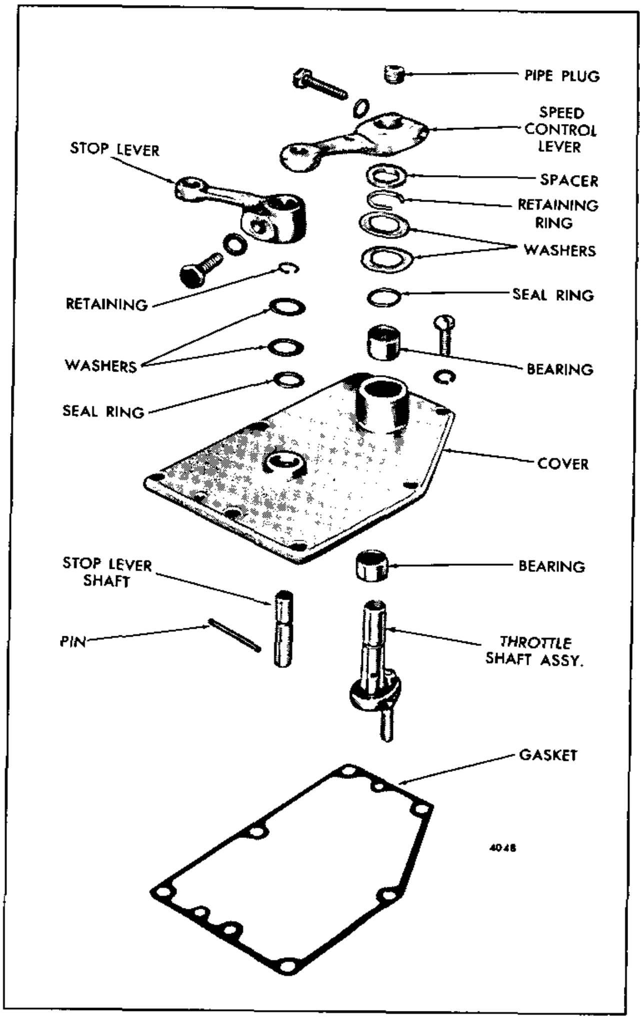


Fig. 4 – Governor Cover Details and Relative Location of Parts

1. *Disconnect the linkage to the governor control levers.*
2. Remove the seven attaching screws and lock washers and detach the governor cover and lever assembly from the governor housing. Remove the cover gasket.
3. Take out the two bolts and copper washers and remove the spring housing (or cover) and gasket from the governor housing.
4. Loosen the high speed spring retainer lock nut (type "A" governor, Fig. 6) with a spanner wrench. Remove the spring retainer and withdraw the spring retainer, idle speed adjusting screw, high speed spring, spring plunger, low speed spring, spring seat and spring cap as a unit.

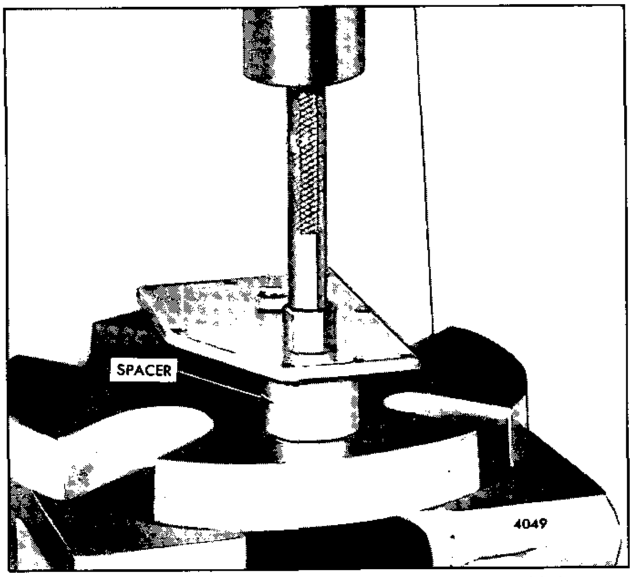


Fig. 5 – Removing Governor Cover Bearing Using Tool J 21967–01

On engines equipped with the type "B" governor (Fig. 6), remove the spring retainer with spanner wrench J 5895 and withdraw the spring assembly.

5. Loosen the hose clamps and slide the hoses back on the fuel rod covers.

6. Remove the valve rocker covers from the cylinder heads.

7. Disconnect the lower fuel rods from the injector control tube levers and from the lower (threaded) ends of the upper fuel rods.

8. Remove the threaded pins that connect the fuel rods to the control link lever and remove the upper fuel rods.

9. Remove the blower drive support (Fig. 3) as outlined in Section 3.4. The governor weight and shaft assembly will be removed with the blower drive support.

10. Check the clearance between the gear and each of the fully extended weights (Fig. 18). If this clearance is less than .100", the weights or carrier are worn and must be replaced.

NOTICE: The current weight carrier is hardened in the weight stop areas and the stop area on the low speed weights has been increased with the use of new center laminations to prevent wear which could allow the weights to open beyond limits and strike the blower drive gear.

11. Remove the governor weight shaft and carrier assembly from the blower drive support, using pry bars if necessary.

12. Remove the blower and governor housing assembly as outlined in Section 3.4.

13. Remove the six attaching bolts and lock washers and detach the governor housing from the blower rear end plate. Remove the gasket.

Disassemble Governor

Before removing any parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect for worn or damaged parts which may be repaired or replaced without complete disassembly.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

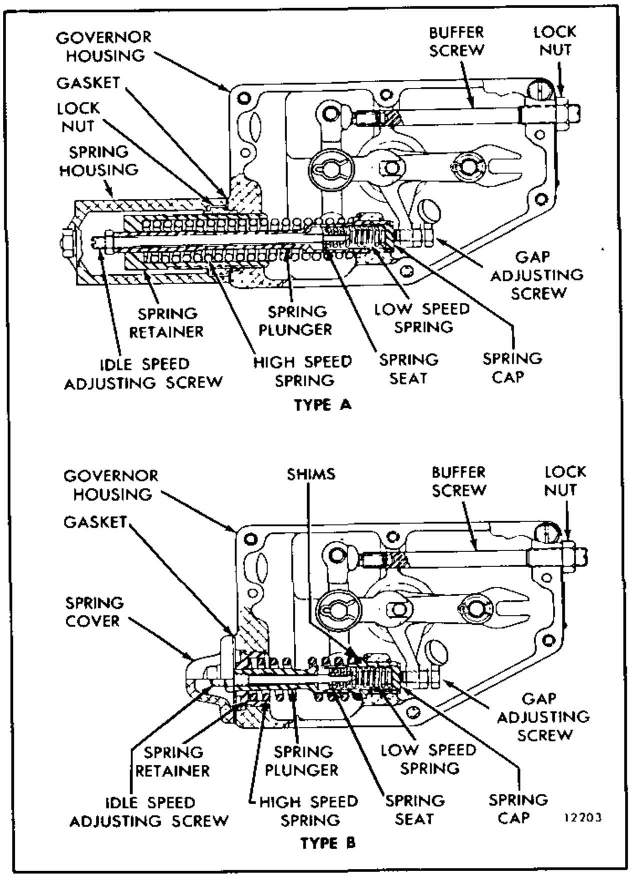


Fig. 6 – Governor Spring Assemblies

Disassemble Governor Cover

Refer to Fig. 4 and disassemble the governor cover as follows:

1. Remove the pipe plug from the throttle shaft.

2. Loosen the clamping bolt and remove the speed control lever.

3. Remove the spacer from the throttle shaft.

4. Remove the retaining ring and two seal retaining washers and withdraw the throttle shaft assembly from the cover.

5. Remove the seal ring from the cover.

6. Loosen the clamping bolt and remove the stop lever.

7. Remove the retaining ring and two seal retaining washers and withdraw the stop lever shaft from the cover.

8. Remove the seal ring from the cover.

9. Wash the governor cover with clean fuel oil and inspect the needle bearings for wear or damage. If the bearings are satisfactory, removal is unnecessary.

10. If the bearings are to be removed, place the governor cover on an arbor press and press them out with bearing remover J 21967–01 (Fig. 5).

Disassemble Governor Springs

Refer to Fig. 6 and disassemble the governor spring assembly as follows:

1. Remove the low speed spring cap, spring, and spring seat from the spring plunger.

2. Depress the high speed spring by hand and remove the idle speed adjusting screw lock nut.

The spring retainer and high speed spring (and shims) may then be withdrawn. Remove the idle speed adjusting screw from the spring plunger.

Disassemble Governor Housing

1. Remove the governor buffer screw and spring.

2. Remove the spring pin and washer from the control link lever pin (Fig. 7) and withdraw the control link lever and washer.

3. If the bearings require replacement, support the control link lever on a sleeve placed on the bed of an arbor press. Then, press the bearings out of the lever with tool J 8985 (Fig. 8).

4. Remove the spring pin and washer from the pin in the operating shaft lever and remove the differential lever.

5. Remove the plug at the bottom of the governor housing.

6. Remove the set screws, if used, from the governor operating fork.

7. Remove the operating shaft upper bearing retaining screw and washer.

8. Remove the operating shaft lower bearing by placing the inverted governor housing on the bed of an arbor press; use wood block(s) to prevent damage to the dowel pins in the housing. Press on the shaft, using a rod small enough to pass through the bearing, until the bearing is free of the shaft. Then, withdraw the bearing.

9. Place an end wrench between the operating fork and the governor housing; also place a rod on the end of the operating shaft and press the shaft out of the fork (Fig. 9).

10. Withdraw the operating shaft, operating shaft lever and bearings.

11. Press the shaft from the operating shaft lever and bearings.

Disassemble Governor Weights and Shaft

1. Remove the retaining rings from the governor weight pins (Fig. 10). Then, drive the pins out by tapping on a punch held against the grooved end of the pins. Remove the governor weights.

2. Press the shaft from the governor weight carrier (Fig. 11).

3. Slide the governor riser and bearing assembly from the shaft. Do not remove the bearing since the bearing and riser are serviced only as an assembly.

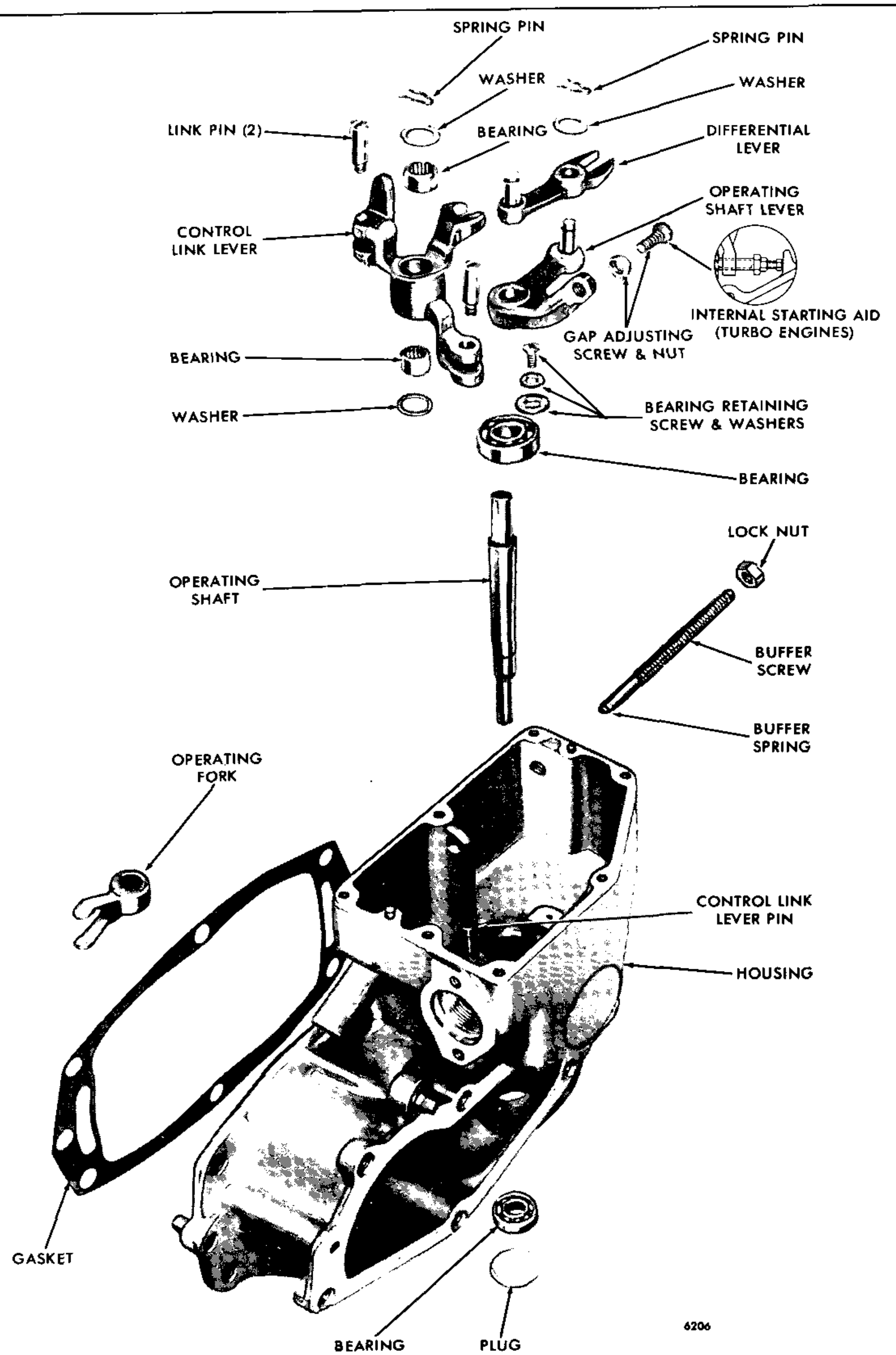


Fig. 7 – Governor Housing Details and Relative Location of Parts

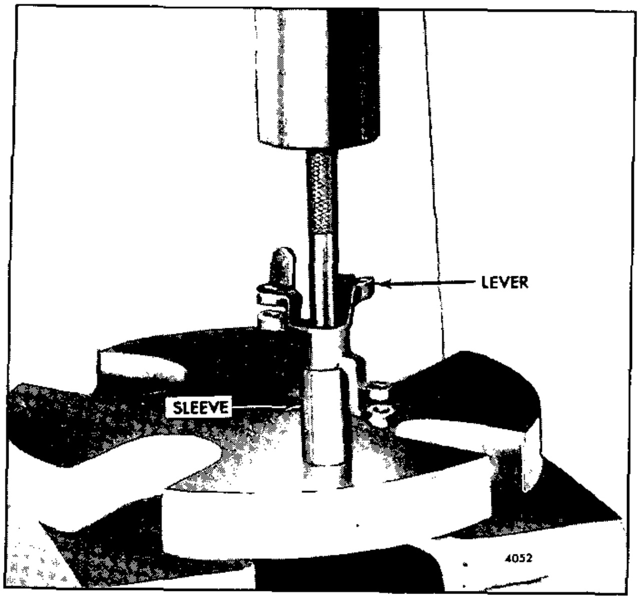


Fig. 8 – Removing Bearings from Control Link Lever Using Tool J 8985

Disassemble Blower Drive

1. Remove the snap ring and the thrust washer from the blower drive gear shaft (Fig. 12). Slide the shaft and gear from the blower drive support.

2. Press the drive gear from the shaft and remove the key.

3. Tap the governor weight shaft bearing from the blower drive support. If the bearing is a tight fit, drive the plug from the support and, using a spacer against the outer race of the bearing, press or tap the bearing from the support.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal *injury, wear adequate eye protection* and do not exceed 40 psi (276 kPa) air pressure.**

Inspect all of the bearings. Replace corroded or pitted bearings. Revolve ball bearings slowly by hand. Replace bearings which indicate rough or tight spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and thrust bearing assembly.

Inspect the control link lever, needle bearings and control link lever *pin for wear.* Replace worn parts. If a new control link lever pin is required, remove the old pin and press the new pin in the governor housing; the pin must project 1.055" to 1.060" above the boss in the housing.

Examine the weight carrier, weights and pins. Replace worn parts. The current weight carrier is hardened in the weight stop areas and the stop area on the low speed weights has been increased with the use of new center laminations.

Inspect the governor springs, spring seat, spring cap, *plunger, spring retainer, adjusting screws and other parts of* the governor housing for wear.

Check the serrations on the governor weight shaft and the drive plate on the blower timing gear for wear. Replace worn Parts.

Assemble Governor Cover

Refer to Fig. 4 and assemble the governor cover as *follows:*

1. Place the cover, with the inner face down, on the bed of an arbor press. Start a needle bearing straight into the bearing bore of the cover, with the number side of the bearing up. Then, insert bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Fig. 13).

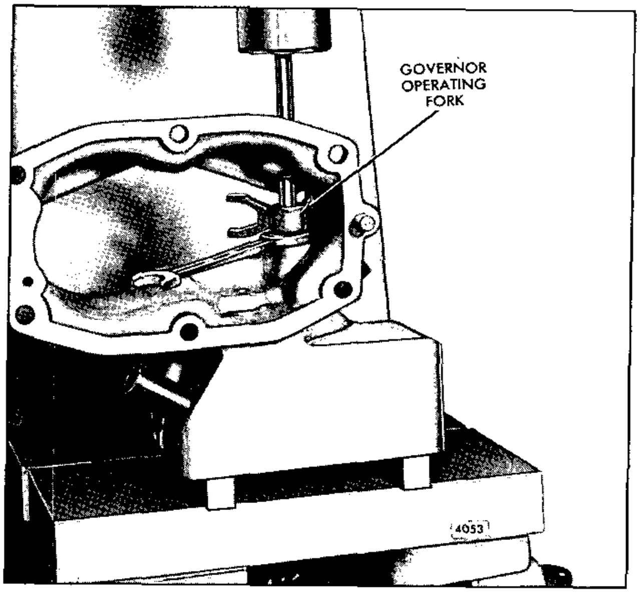


Fig. 9 – Removing Governor Operating Fork

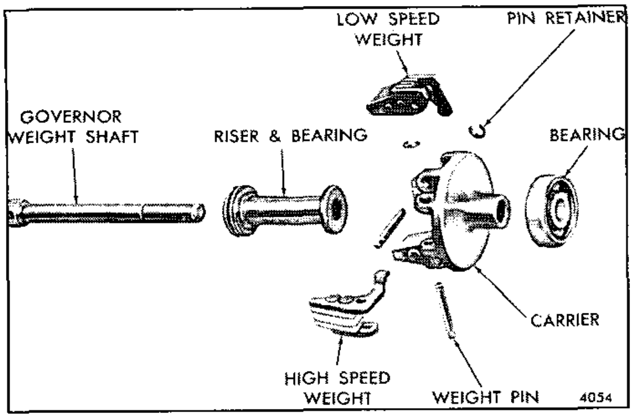


Fig. 10 – Governor Weight Details and Relative Location of Parts

2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Press the bearing in flush with the cover with tool J 21068.

NOTICE: To prevent possible damage do not use impact tools to install needle bearings.

3. Install the pipe plug in the tapped hole in the throttle shaft.

4. Pack the needle bearings with grease. Then, slide the throttle shaft assembly through the bearings, with the fulcrum lever pin seated in the slot on the underside of the cover.

5. Install a new seal ring on top of the upper bearing. Then, install the two seal retaining washers and the retaining ring. A .0329" thick, 33/64" I.D. x 43/64" O.D. seal ring back-up washer is used in place of the lower washer on certain governor covers.

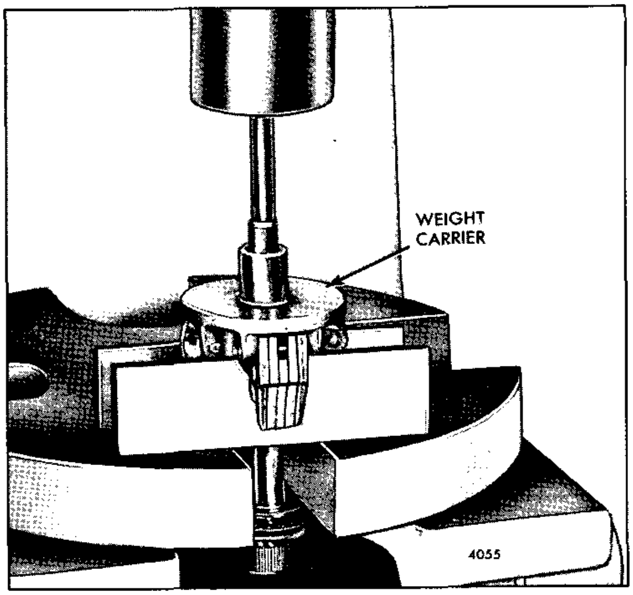


Fig. 11 – Removing Shaft from Weight Carrier

6. Lubricate the stop lever shaft with engine oil. Then, slide the shaft through the cover.

7. Install a new seal ring over the shaft. Then, install the two seal retaining washers and the retaining ring. A .0329" thick, 25/64" I.D. x 17/32" O.D. seal ring back-up washer is used in place of the lower washer on certain governor covers.

8. Install the .078" thick spacer over the speed control shaft and against the retaining ring.

9. Install the stop lever and speed control lever, then tighten the clamping bolts. Be sure the speed control lever contacts the spacer.

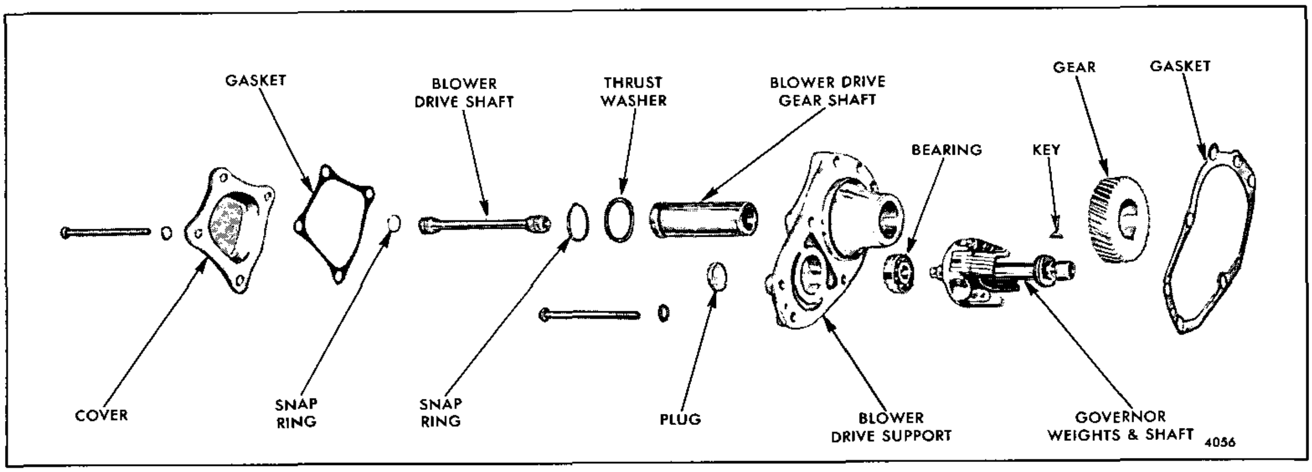


Fig. 12 – Blower Drive Support Assembly Details and Relative Location of Parts

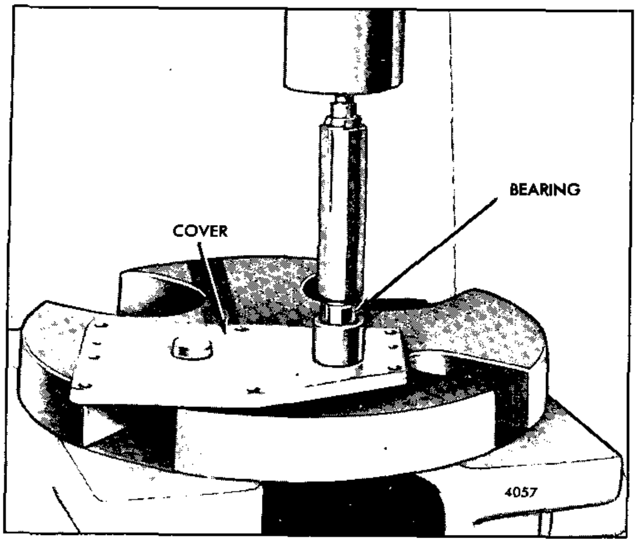


Fig. 13 – Installing Governor Cover Bearings Using Tool J 21068

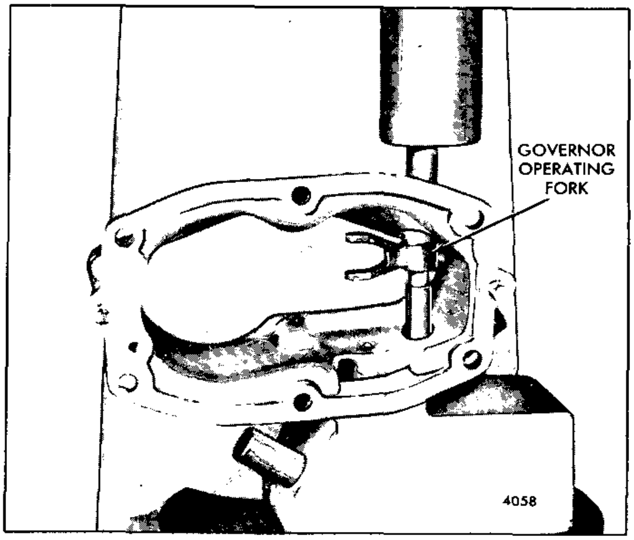


Fig. 14 – Installing Governor Operating Fork on Shaft

Assemble Governor Housing

Refer to Fig. 7 and assemble the governor housing as follows:

1. Start the upper operating shaft bearing, number side up, on the end of the shaft. Support the lower end of the shaft on an arbor press. Place a sleeve on the inner race and press the bearing against the shoulder on the shaft.

2. Start the operating shaft lever, with the pivot pin up, on the end of the shaft with the flat on the shaft registering with the flat in the lever bore. Use a sleeve to press the lever tight against the bearing.

3. Insert the lever and shaft assembly through the top of the governor housing. Position the operating fork over the lower end of the shaft, with the finished cam surfaces facing toward the rear of the governor (toward the governor drive).

4. Support the operating shaft and governor housing on the bed of an arbor press with the upper end of the shaft resting on a steel block (Fig. 14). Align the flat in the fork with the flat on the shaft, then place a sleeve over the shaft and against the fork. Press the fork tight against the shoulder on the shaft. Install the set screw and lock screw, if used, in the fork.

5. Start the lower operating shaft bearing, number side up, on the end of the shaft. Place a sleeve on the inner race and press the bearing against the shoulder in the housing.

6. Lubricate both bearings with engine oil.

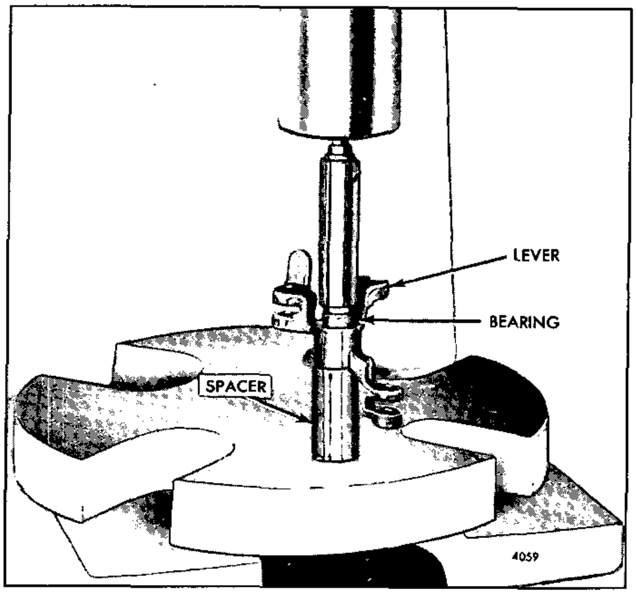


Fig. 15 – Installing Bearings in Control Link Lever Using Tool J 21068

7. Apply a good quality sealant around the edge of a new expansion plug and tap it in place in the housing.

8. Secure the upper operating shaft bearing in place with a retaining screw and flat washer.

9. Place the differential lever over the pivot pin in the operating shaft lever (Fig. 7). Secure the lever with a washer and spring pin.

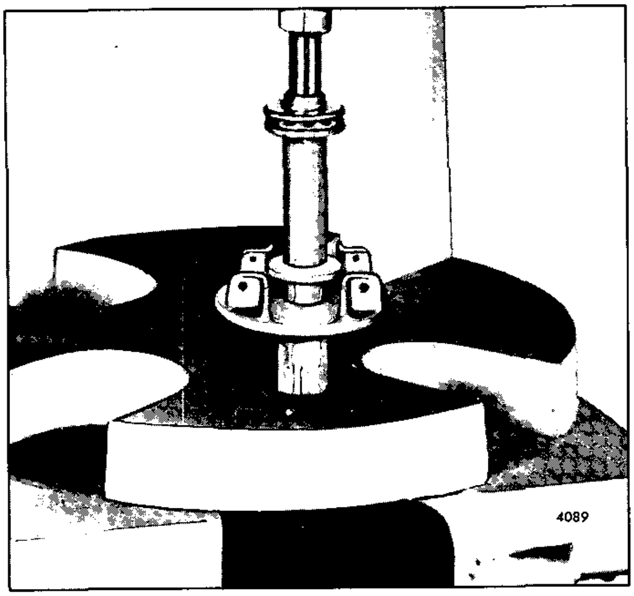


Fig. 16 – Installing Weight Carrier on Shaft Using Tool J 8984

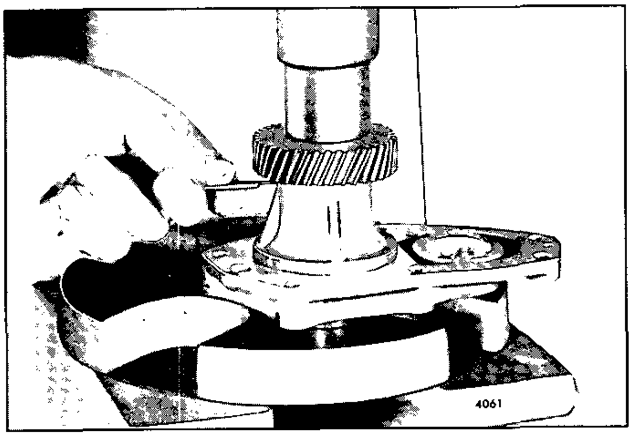


Fig. 17 – Installing Blower Drive Gear on Shaft

10. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

11. Support the control link lever on a steel spacer on the bed of an arbor press. Start one bearing, number side up, in the lever and press it flush with the lever with tool J 21068 (Fig. 15). Invert the lever and install the second bearing in the same manner.

12. Place the washer on the control link lever pin in the housing. Pack the needle bearings with grease and install the lever, with the tapped end of the link pin holes down, over the pin in the governor housing (Fig. 7). Secure the lever with the washer and spring pin.

13. Thread the buffer screw into the governor housing until it extends 9/16" to 5/8" beyond the governor housing and install the lock nut.

NOTICE: The buffer screw on early governors threaded into a splined lock nut which was installed (inside the housing) in a drilled hole in the governor housing. The current buffer screw threads into a tapped hole in the housing and is secured with a lock nut which is installed from the outer side of the housing.

Assemble Governor Weights and Shaft

Refer to Fig. 10 and assemble the governor weights and shaft as follows:

1. Lubricate the governor weight shaft with clean engine oil and slide the riser assembly over the shaft, with the bearing end toward the serrated end of the shaft. Pack the bearing with grease.

2. Use installer J 8984 as illustrated in Fig. 16 and press the shaft into the weight carrier. The tool will properly position the carrier on the shaft.

3. Position the low speed weights, identified by the short cam arm, on opposite sides of the weight carrier. Drive the weight pins in place and install the retaining rings. To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Then, drive the knurled end in just enough so the retaining ring can be installed on the pin.

4. Install the high speed weights in a similar manner. The high speed weights are identified by the long cam arm.

Assemble Blower Drive

Refer to Fig. 12 and assemble the blower drive as follows:

1. Place the blower drive support, with the inner face up, on the bed of an arbor press. Start the governor weight shaft bearing, numbered side up, into the bore of the support. Place a suitable sleeve against the outer race and press the bearing against the shoulder of the blower drive support.

2. Place the steel thrust washer on the end of the blower drive gear shaft and secure it in place with the snap ring.

3. Lubricate the blower drive gear shaft with engine oil and install it in the blower drive support.

4. Install the key in the shaft, then place the blower drive support on an arbor press. Lubricate the inner diameter of the blower drive gear and start it straight on the shaft, with the keyway in the gear aligned with the key in the shaft. Place a spacer over the gear and press the gear on the shaft until a .005" feeler gage may just be withdrawn (Fig. 17).

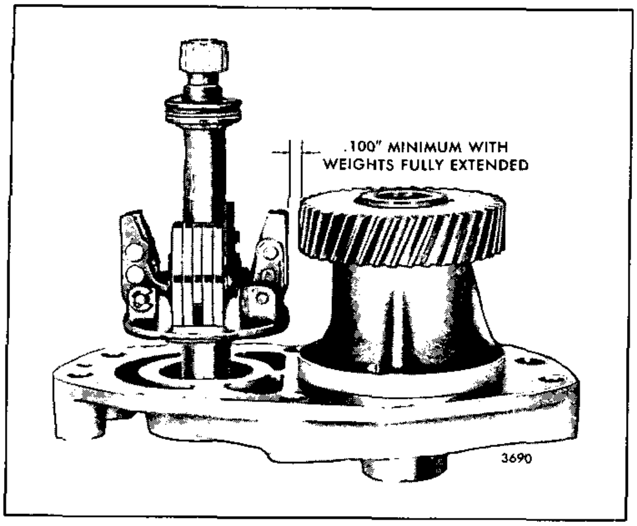


Fig. 18 – Minimum Clearance Between Blower Drive Gear and Governor Weights

5. Place a support under the inner race of the bearing in the blower drive support and start the weight end of the governor weight shaft into the bearing. Press the shaft in until the shoulder on the shaft contacts the inner race of the bearing. Press the shaft in straight to avoid brinelling the bearing.

6. Apply a good quality sealant on the edge of the cup plug and press the plug in flush with the blower drive support.

7. Check the clearance between the fully extended governor weights and the blower drive gear. This clearance must not be less than .100" (Fig. 18).

Install Governor

Install the governor on the engine as follows:

1. Attach a new gasket to the governor housing and place the housing against the blower rear end plate. Secure the governor housing to the blower with six bolts and lock washers.

2. Install the blower and governor assembly on the engine as outlined in Section 3.4.

3. Install the blower drive support assembly as outlined in Section 3.4 under *Install Blower in 6V Engine.*

4. Insert the upper fuel rods through the fuel rod covers, hoses and clamps and attach the fuel rods to the governor control link lever. Then, thread the link pins into the lever.

5. Attach the lower fuel rods to the injector control tube levers and to the upper fuel rods.

6. Slide the fuel rod cover hoses in place and secure them with the hose clamps.

7. Assemble the governor springs as follows:

TYPE A (Fig. 6):

a. Thread the lock nut on the spring retainer.

b. Thread the idle speed adjusting screw into the spring plunger.

c. Place the high speed spring over the spring plunger (with the close wound coils toward the idle screw end of the plunger).

d. Lubricate the spring and plunger assembly with engine oil. Then, install the spring and plunger assembly in the spring retainer and secure it in place with a lock nut. Approximately 1/4" of the idle speed adjusting screw should extend beyond the lock nut.

e. Lubricate and insert the spring seat, low speed spring, and spring cap in the open end of the spring plunger.

f. Place a new gasket over the spring retainer and thread the retainer and spring assembly into the governor housing. Tighten the lock nut finger–tight until the engine tune–up is performed.

TYPE B (Fig. 6):

a. Thread the idle speed adjusting screw into the spring plunger.

b. Reinstall the original shims over the spring plunger.

c. Place the high speed spring over the spring plunger.

d. Lubricate the spring and plunger assembly with engine oil. Then, place the spring retainer over the plunger and secure it with a lock nut. Approximately 1/4" of the idle speed adjusting screw should extend beyond the lock nut.

e. Lubricate and insert the spring seat, low speed spring and spring cap in the open end of the spring plunger.

f. Thread the retainer and spring assembly into the governor housing. The cover and gasket are to be installed after the engine tune–up is performed.

8. Place a new gasket on the governor housing and install the cover and lever assembly. Make sure the control link lever engages the pin on the differential lever. Also, be sure the pin in the speed control shaft enters the slot in the differential lever and that the pin in the stop lever shaft is engaged between the stop on the underside of the cover and the vertical extension of the control link lever. Then, secure the cover with seven screws and lock washers.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assemble, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

9. Connect the linkage to the governor control levers after the engine tune-up is performed.

10. Perform an engine tune-up as outlined in Section 14.

LIMITING SPEED MECHANICAL GOVERNOR

8V ENGINE

The limiting speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idling speed.

2. Limits the maximum operating speed of the engine.

The double–weight governor, identified by the letters D.W.–L.S. stamped on the governor name plate, is mounted on the front end of the blower and is driven by the left–hand helix blower rotor shaft (Fig. 2).

The governor consists of four basic sub–assemblies: a cover and lever assembly, governor housing, spring housing, and a weight and shaft assembly.

The turbocharged engines use a starting aid screw threaded into the gap adjusting screw. The starting aid screw is threaded in the low–speed gap adjusting screw so that its head contacts the governor housing wall (Fig. 1). Both the gap adjusting screw and the starting aid screw have a nylon locking patch on the threads in place of lock nuts.

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In the RUN position, the stop lever holds the fuel injector racks near the full–fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

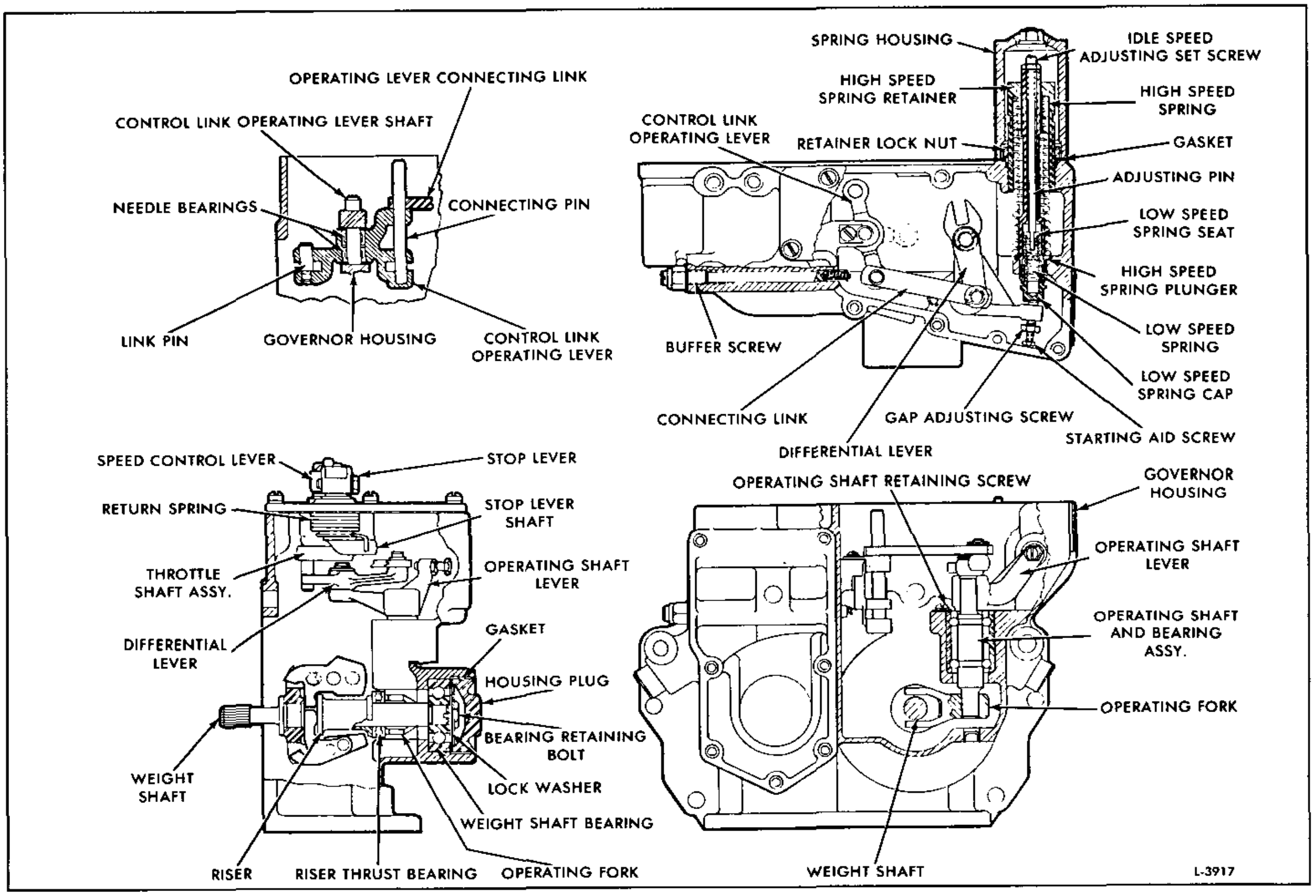


Fig. 1 - Limiting Speed Governor for 8V-53 Engine

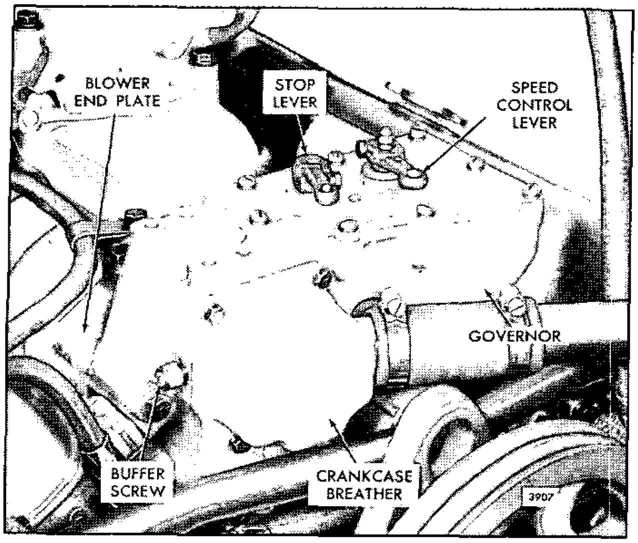


Fig. 2 – Governor Mounting

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever bears against the governor spring cap while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the governor springs. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the high speed spring or low speed spring (depending on the speed range). When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

In the low speed range, the centrifugal force of the low speed weights and the high speed weights operates against the low speed spring. As the engine speed increases, the centrifugal force of both pairs of weights compresses the low speed spring until the low speed weights have reached the limit of their travel at which time the low speed spring is fully compressed and the spring cap is within .0015" of the high speed spring plunger.

Throughout the intermediate speed range, the operator has complete control of the engine because both the low speed spring and the low speed weights are against their stops, and the high speed weights are not exerting enough force to overcome the high speed spring.

As the engine speed continues to increase, the centrifugal force of the high speed weights increases until this force overcomes the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

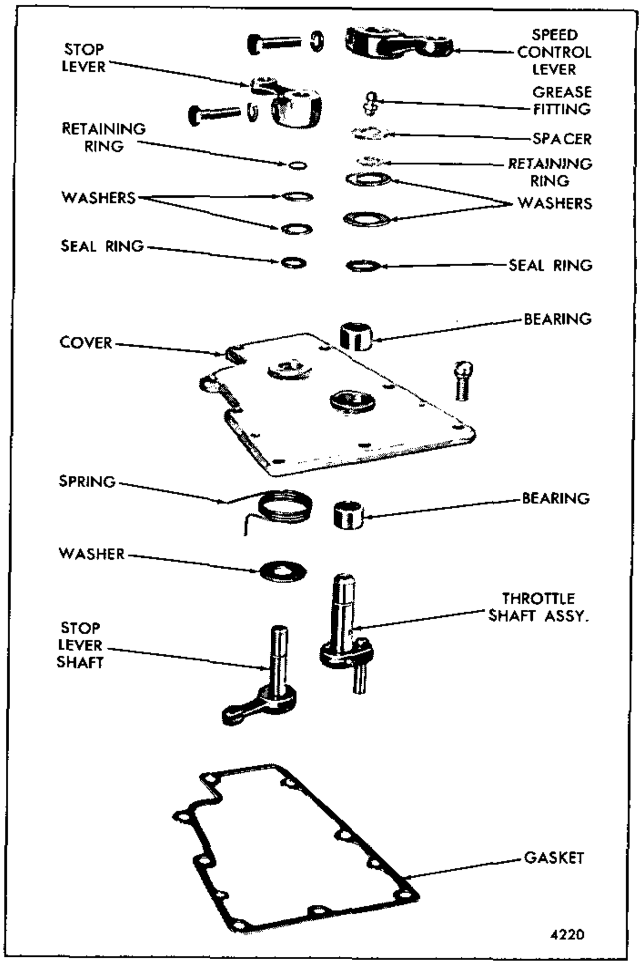


Fig. 3 – Governor Cover Details and Relative Location of Parts

Fuel rods are connected to the differential lever and the injector control tube levers through the control link operating lever and the connecting link (Fig. 1). This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no–fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.

Lubrication

The governor is lubricated by a spray of oil from a passage in the blower end plate. The revolving governor weights distribute this oil to all parts of the governor which require lubrication. Excess oil returns to the engine crankcase through passages in the blower end plate and the cylinder block.

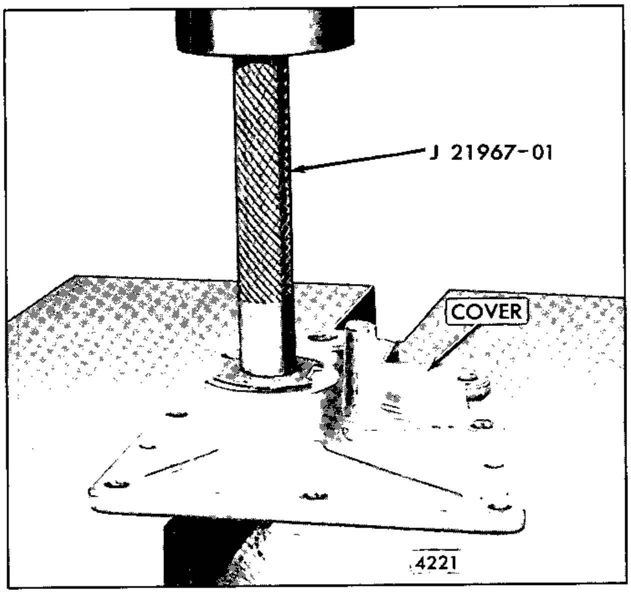


Fig. 4 – Removing Governor Cover Bearings

Remove Governor From Engine

Check the operation of the governor as outlined in Section 2.7 and if it fails to control the engine properly, remove and disassemble it for further inspection.

The blower and governor must be removed together as outlined under *Remove Blower (8V–53)* in Section 3.4.1. Then remove the governor from the blower as outlined under *Remove Accessories from Blower (8V–53)* in Section 3.4.1.

Disassemble Governor

Before removing any parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect for worn or damaged parts which may be repaired or replaced without complete disassembly.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Disassemble Governor Cover

Refer to Fig. 3 and disassemble the governor cover as follows:

1. Loosen the clamping bolt and remove the stop lever.
2. Remove the retaining ring and withdraw the two washers from the stop lever shaft assembly.
3. Note the position of the stop lever shaft assembly and the lever return spring. Then withdraw the shaft, washer and spring
4. Remove the seal ring.
5. Loosen the clamping bolt and remove the speed control lever.
6. Remove the spacer from the throttle shaft.
7. Remove the retaining ring and withdraw the two washers from the throttle shaft assembly.
8. Withdraw the throttle shaft assembly. Remove the grease fitting from the shaft.
9. Remove the seal ring.
10. Wash the governor cover with clean fuel oil and inspect the needle bearings for wear or damage. If the bearings are satisfactory, removal is unnecessary.
11. If the bearings are to be removed, place the governor cover on an arbor press and press them out with bearing remover J 21967–01 (Fig. 4).

Disassemble Governor Springs

Refer to Fig. 5 and disassemble the governor spring housing as follows:

1. Remove the two retaining bolts and copper washers and withdraw the spring housing from the governor.
2. Loosen the spring retainer lock nut with a spanner wrench. Remove the spring and retainer assembly from the governor. Remove the fasket.
3. Remove the spring cap and low speed spring.
4. Loosen the lock nut and remove the idle speed adjusting screw. Then withdraw the high speed spring and plunger from the spring retainer.

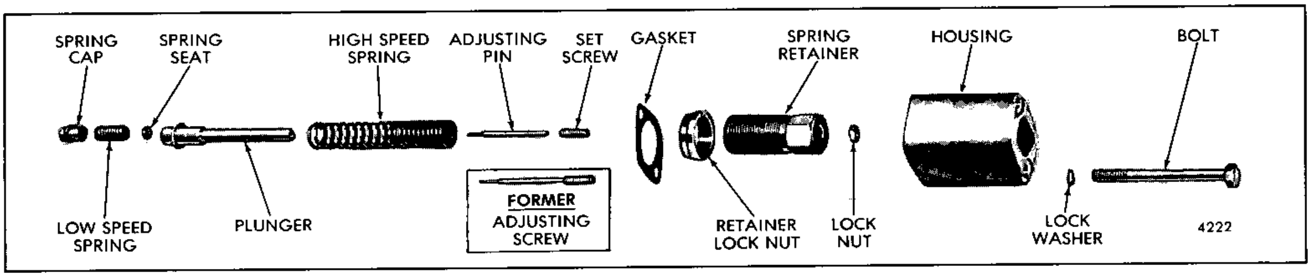


Fig. 5 – Governor Spring Assembly Details and Relative Location of Parts

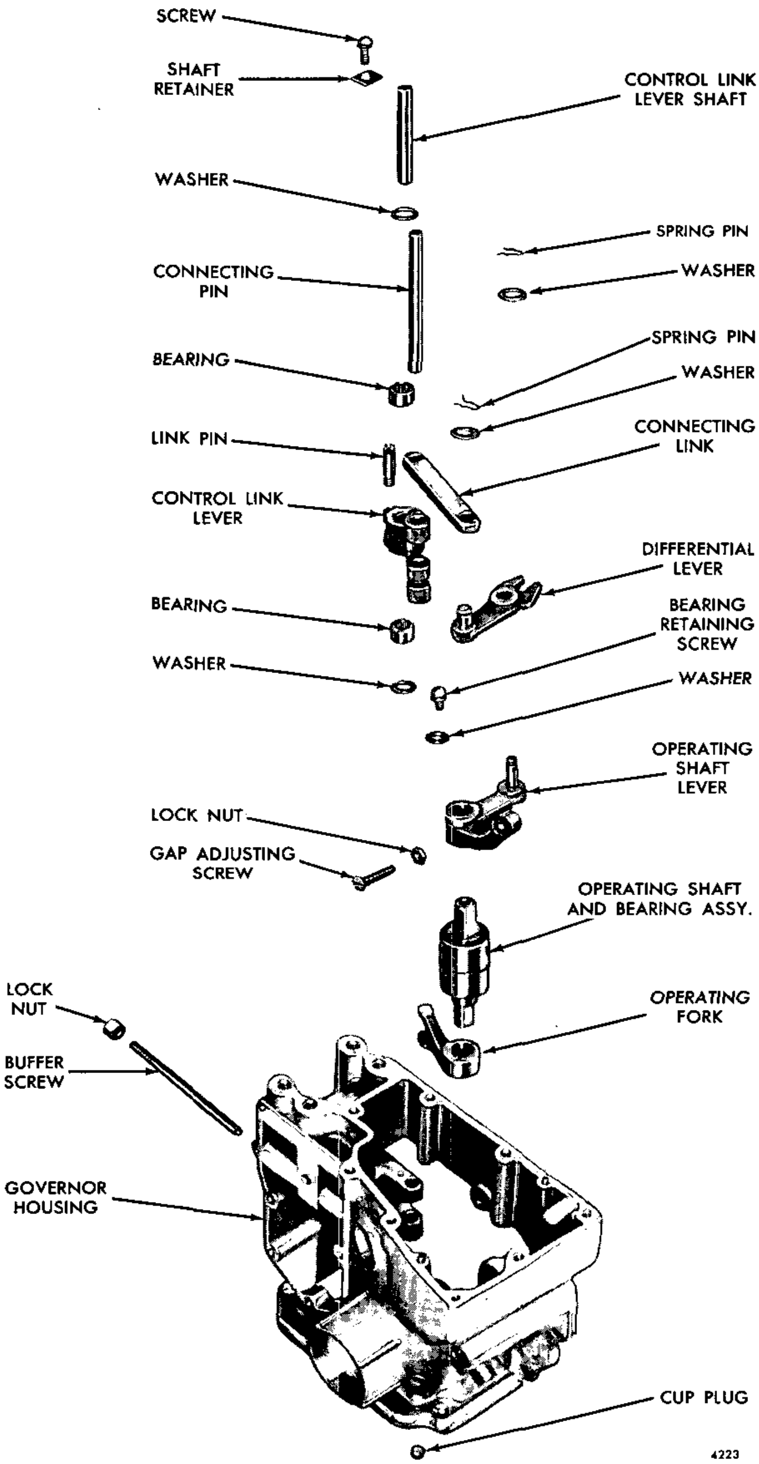


Fig. 6 – Governor Housing Details and Relative Location of Parts

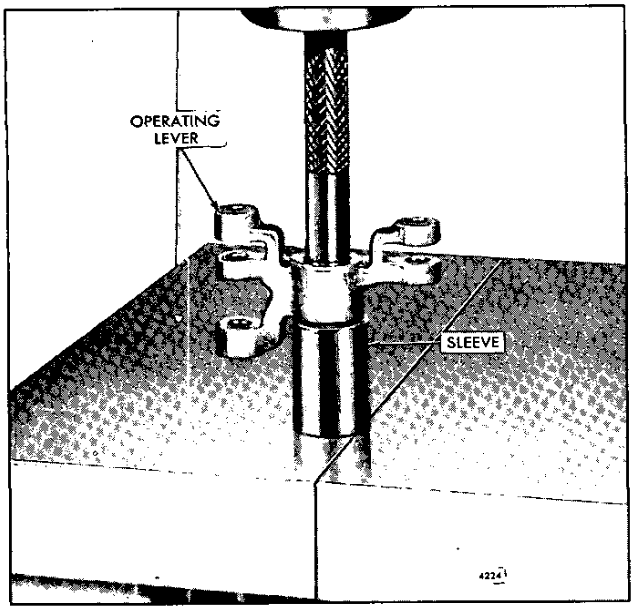


Fig. 7 – Removing Control Link Lever Bearings

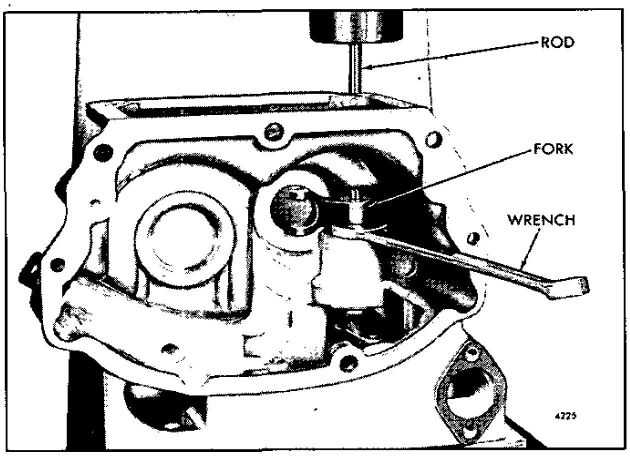


Fig. 8 – Removing Governor Operating Fork

Disassemble Governor Housing

Refer to Figs. 6 and 9 and disassemble the governor housing as follows:

1. Remove the large plug and gasket from the governor housing to provide access to the weight shaft bearing.
2. Straighten the tang on the lock washer and remove the weight shaft bearing retaining bolt, washer and lock washer.
3. Withdraw the weight, riser and shaft assembly.
4. Remove the weight shaft bearing from the governor housing.
5. Loosen the lock nut and remove the buffer screw.
6. Remove the two link pins from the control link lever.
7. Remove the spring pin and washer and remove the connecting link.
8. Remove the spring pin and washer and remove the differential lever.
9. Remove the control link lever shaft retainer and screw. Then withdraw the control link lever, shaft and two washers from the governor housing.
10. Examine the needle bearings. If they are satisfactory for further use, removal is unnecessary.
11. If the bearings require replacement, support the control link lever on a sleeve placed on the bed of an arbor press. Then press the bearings out of the lever with bearing remover J 8985 (Fig. 7).
12. Remove the operating shaft bearing retaining screw and washer.
13. Tap the small cup plug out of the housing.
14. Place the governor housing, upside down, on wood blocks on the bed of an arbor press. Then place an end wrench between the operating shaft fork and the boss in the housing. Insert a rod through the cup plug hole in the housing and against the end of the shaft, then press the shaft out of the fork (Fig. 8).
15. Withdraw the operating shaft, bearing and lever assembly.
16. If the operating shaft bearing requires replacement, use a small puller to remove the lever from the shaft.

Disassemble Governor Weights and Shaft

Refer to Fig. 9 and disassemble the governor weights as follows:

1. Remove the riser thrust bering and riser tube from the weight shaft.
2. Remove the retaining rings from the weight pins. Then drive the pins out of the carrier and the weights by tapping on the grooved end of the pins. Remove the governor weights.

Inspection

Clean all of the parts (except the operating shaft bearing) with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

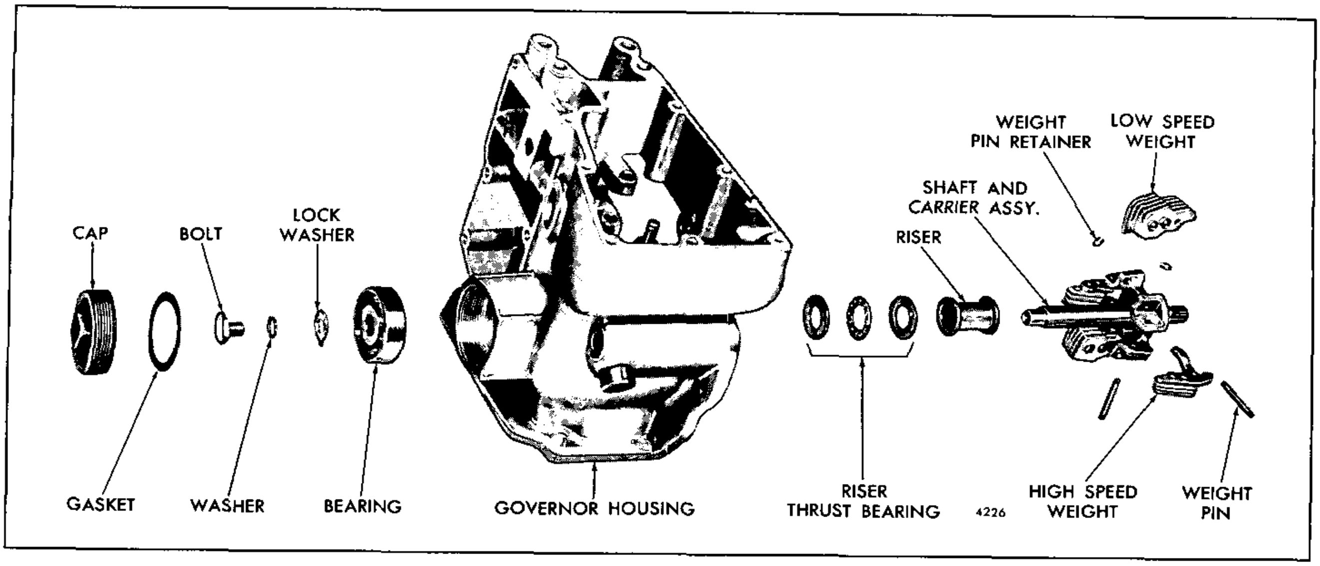


Fig. 9 – Governor Weight Details and Relative Location of Parts

NOTICE: *The operating shaft bearing is* sealed and must not be cleaned with fuel oil or other cleaning agent.

Inspect all bearings. Replace corroded or pitted bearings. Revolve ball bearings slowly by hand; replace bearings which indicate rough or tight spots. The operating shaft and bearing are serviced only as an assembly.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Inspect all of the levers, pins, shafts, governor weights and springs. Replace worn or damaged parts.

Assemble Governor Cover

Refer to Fig. 3 and assemble the governor cover as follows:

1. Place the cover, with the inner face down, on a spacer on the bed of an arbor press. Start a needle bearing straight into the bearing bore of the cover, with the number side of the bearing up. Then insert bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Fig. 10).

2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Press the bearing in flush with the cover with tool J 21068.

   NOTICE: To avoid bearing damage, do not use impact tools to install needle bearings.

3. Install the grease fitting in the throttle shaft.

4. Pack the needle bearings with grease. Then slide the throttle shaft assembly through the bearings, with the fulcrum lever pin seated in the slot on the underside of the cover.

5. Install a new seal ring on top of the upper bearing. Then install the two seal retaining washers and the retaining ring.

6. Place the large washer over the stop lever shaft. Then place the spring, with the hook end down, over the shaft. Insert the shaft in the cover with the lever against the stop in the cover; position the spring with the hook behind the lever and the upper extended end of the spring located between the lever stop and the shaft boss in the cover.

7. Install a new seal ring over the shaft. Then install the two seal retaining washers and the retaining ring.

8. Install the .078" thick spacer over the speed control shaft and against the retaining ring.

9. Install the stop lever and the speed control lever; tighten the clamping bolts. Be sure the speed control lever contacts the spacer.

Assemble Governor Housing

Refer to Fig. 6 and assemble the governor housing as follows:

1. Start the operating shaft lever on the shaft with the flat surfaces aligned and press the lever flush with the top of the shaft.

2. Insert the shaft, bearing and lever assembly in the governor housing.

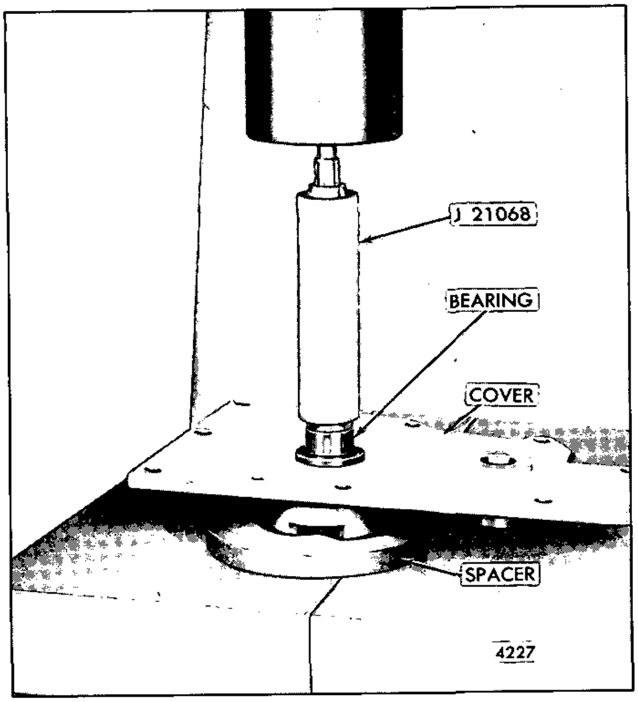


Fig. 10 – Installing Governor Cover Bearings

3. Place the housing right side up on the bed of as arbor press.

4. Align the flat surfaces and start the operating shaft fork on the shaft with the finished cam surfaces of the fork facing toward the rear of the governor. Insert the threaded end of tool J 21995–2 through the cup plug hole in the housing. Then thread the knurled nut J 21995–1 on the end of the tool so the fork rests on the nut. Use a rod of suitable length and diameter and press the shaft into the fork until the fork is flush with the end of the shaft (Fig. 11). Remove the tools.

5. Install the operating shaft bearing retaining screw and washer.

6. Apply a good quality sealant to a new cup plug and press the plug in the governor housing.

7. Place the differential lever over the pin in the operating shaft lever and secure it with a washer and spring pin.

8. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

9. Support the control link lever on a steel spacer on the bed of an arbor press. Start one bearing, number side up, in the lever and press it flush with the lever with tool J 21068 (Fig. 12). Invert the lever and install the second bearing in the same manner.

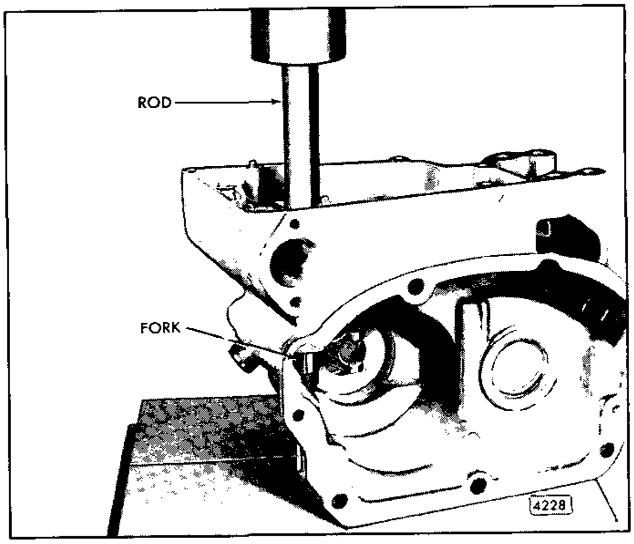


Fig. 11 – Installing Governor Operating Fork

NOTICE: To avoid bearing damage do not use impact tools to install needle berings.

10. Pack the needle bearings with grease, place a washer over each bearing and insert the control link lever between the two bosses in the housing (Fig. 1). Insert the control link lever shaft, then insert the shaft retainer in the notch of the shaft and fasten it to the housing with the retaining screw.

11. Place the connecting pin in the control link lever, then place the connecting link over the connecting pin and the pin in the differential lever. Secure the link to the differential lever with a washer and spring pin.

12. Thread the short link pin into the control link lever.

13. Install the buffer screw and lock nut.

Assemble Governor Springs

Refer to Fig. 5 and assemble the governor springs as follows:

1. Thread the lock nut on the high speed spring retainer approximately 1–1/2″. Place the high speed spring over the spring plunger with the loosely wound end of the spring against the shoulder of the plunger.

2. Insert the plunger and spring assembly in the spring retainer. Thread the idle speed adjusting screw approximately 1/2″ into the tapped end of the plunger. Thread the lock nut on the idle speed adjusting screw.

3. Insert the spring cap in one end of the low speed spring and the small end of the spring seat in the other end of the spring.

4. Insert the spring seat end of the spring, cap and seat assembly in the spring plunger, with the spring seat against the shoulder on the idle screw.

5. Place the spring housing gasket over the springs and against the shoulder on the spring retainer lock nut. Then thread the spring retainer in the governor housing, with the spring cap against the gap adjusting screw in the operating shaft lever. Tighten the lock nut.

6. The spring housing may be installed after the engine tune–up (Section 14) is performed.

Assemble Governor Weights

Refer to Fig. 9 and assemble the weights, shaft and riser as follows:

1. Position the low speed weights, identified by the short cam arm, on opposite sides of the weight carrier. Drive the weight pins in place and install the retaining rings. To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Then drive the knurled end in just enough so the retaining ring can be installed on the pin.

2. Install the high speed weights in a similar manner.

3. Lubricate the weight shaft with clean engine oil and slide the riser tube on the shaft.

4. Pack the riser thrust bearing with grease. Then assemble the bearing on the weight shaft, with the bearing race having the smaller inside diameter against the riser.

5. Insert the shaft, weight and riser assembly in the governor housing.

6. Support the splined end of the shaft on the bed of an arbor press. Start the weight shaft bearing in the governor housing and over the end of the shaft. Place a sleeve against the inner race and press the bearing in the housing and against the shoulder on the shaft.

7. Place a flat washer and lock washer over the bearing retainer bolt. Thread the bolt into the tapped end of the shaft and tighten it. Bend the tang on the lock washer against the flat on the head of the bolt.

8. Place a gasket against the weight shaft bearing. Clean the plug with solvent to remove any oil or grease before applying the sealant. Apply a sealant such as Loctite grade H, HV, HVW or equivalent onto the threads of the governor housing and the plug. Thread the plug into the housing and tighten the plug to 45 lb–ft (61 N·m) torque.

Install Governor

1. Refer to Section 3.4.1 and attach the governor to the blower as outlined under *Attach Accessories to Blower (8V–53)*.

2. Install the blower and governor assembly as outlined under *Install Blower (8V–53)* in Section 3.4.1.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop position*. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

3. Install the crankcase breather assembly as outlined in *Ventilating System*, Section 4.8.

4. Perform and engine tune–up as outlined in Section 14.

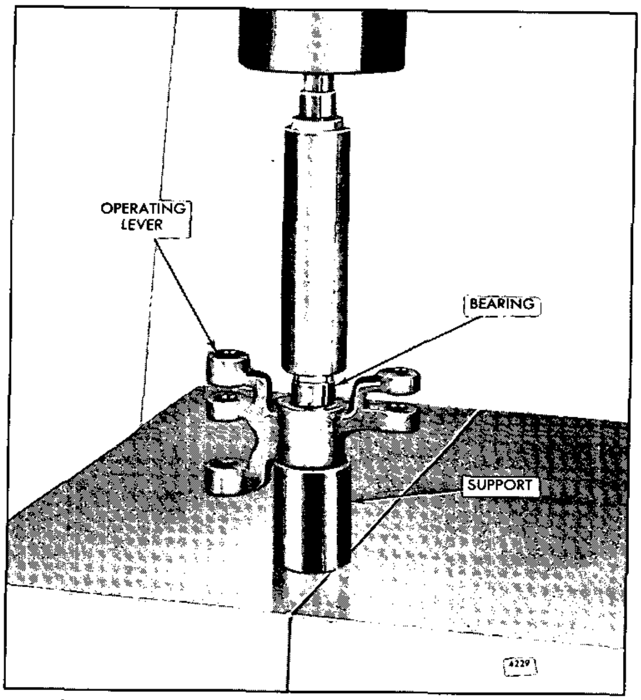


Fig. 12 – Installing Control Link Lever Bearings

LIMITING SPEED MECHANICAL GOVERNOR

(Variable Low-Speed)

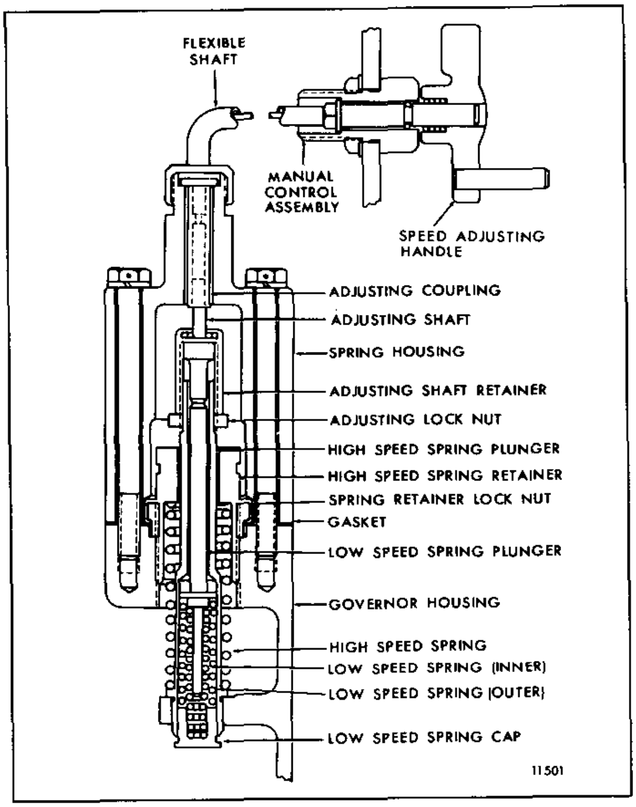


Fig. 1 – Cable Operated Governor Spring Housing and Components

The variable low–speed limiting speed mechanical governor used on In–Line and 6V–53 highway vehicle engines is of the double–weight type. It is used where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain or liquids) and a 500 to 1200 rpm idle speed range is desired during the auxiliary operation. A service kit is available to convert the short spring pack 6V–53 double weight limiting speed governor assembly to a cable operated variable low–speed limiting speed governor for 500–1600 rpm idle speed range for auxiliary operations.

Governor identification is provided by a name plate attached to the governor housing. The letters V.L.S.L.S. stamped on the name plate denote a variable low–speed limiting speed mechanical governor.

- Conversion kits which provide existing limiting speed governors with variable low speed–limiting speed capability are available from DDC parts distributors.

Operation

During highway operation, the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle, on the cable operated governor (Fig. 1), is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor (Fig. 3), the engine speed is changed to the speed required by increasing or decreasing the air supply pressure to the governor. The governor then functions as a variable speed governor, maintaining a constant speed when the load is constantly changing, during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop, then turned ahead about one–quarter of a turn. The air operated governor's air supply pressure must be vented before resuming highway operations.

Lubrication

The governor is lubricated in the same manner as the limiting speed mechanical governor (Section 2.7.1 or 2.7.1.1).

Check Governor Operation

Governor difficulties should be checked out in the same manner as outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

CABLE OPERATED GOVERNOR

Remove Governor From Engine

1. Disconnect the manual control flexible shaft from the governor spring housing.

2. Remove the governor following the same procedures outlined in Section 2.7.1 or 2.7.1.1.

Disassemble Governor

The variable low–speed limiting speed governor is similar to the limiting speed governor with the exception of the spring housing and its components. Therefore, disassemble the governor as outlined in Section 2.7.1 or 2.7.1.1, then disassemble the spring housing and its components (Fig. 1) as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.

2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket.

3. Remove the adjusting coupling from the adjusting shaft.

4. Hold the adjusting lock nut with a wrench and back off the retainer and adjusting shaft.

5. Unscrew the adjusting shaft from the retainer.

6. Unscrew the idle adjusting lock nut from the end of the high–speed spring plunger.

7. Unscrew the high–speed spring retainer lock nut and remove the high–speed spring retainer, plunger and spring along with the low–speed spring plunger, inner and outer springs and low–speed spring cap as an assembly from the governor housing.

8. Remove the high–speed spring retainer and spacer assembly and spring from the high–speed spring plunger. Remove the low–speed spring cap from the opposite end of the high–speed spring plunger and remove the low–speed spring plunger along with the inner and outer low–speed springs.

   The high–speed spring retainer on early engines did not include a spacer. If the shaft sticks in the retainer, *replace it with the current retainer and spacer* assembly.

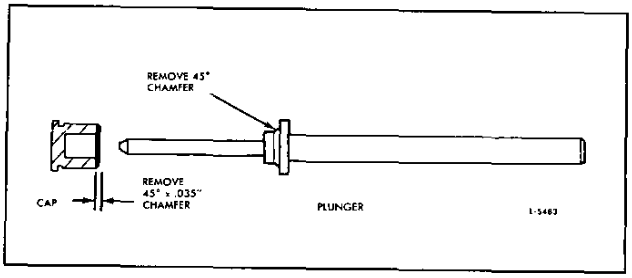


Fig. 2 – Rework Former Plunger and Cap

Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, then inspect them as outlined in Section 2.7.1 or 2.7.1.1.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Assemble Governor

During assembly, lubricate all spring housing components and needle bearing assemblies with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1 or 2.7.1.1, then assemble the spring housing and components (Fig. 1).

To assure a 500 rpm idle speed, the spring seat chamfer has been removed from the low–speed spring plunger and cap. The internal chamfer has been removed from both ends of the coil of the outer low–speed spring. A high idle condition could be the result if an unchamfered spring did not seat properly due to the chamfer on the former plunger and cap. To correct this condition, install a current (modified) plunger and cap, or remove the 45° chamfer from the spring seat area of the plunger and also the 45° x .035" chamfer on the cap (shaded area, Fig. 2).

NOTICE: A chamfered spring should not be used with an unchamfered plunger and cap, because a severe wear condition will result.

1. Thread the spring retainer lock nut on the high–speed spring retainer approximately 1 1/2".

2. Place the high–speed spring on the high–speed spring plunger.

3. Insert the high–speed spring and plunger assembly in the high–speed spring retainer.

4. Insert the low–speed spring plunger into the high–speed spring plunger.

5. Place the inner and outer springs in the lower end of the high-speed spring plunger, over the low-speed spring plunger.

6. Install the low-speed spring cap over the end of the inner low-speed spring and into the end of the high-speed spring plunger and install the assembly in the governor housing. *Place the spring housing gasket in position before installing the assembly.*

7. Thread the idle speed adjusting lock nut on the threaded end of the high-speed spring plunger approximately 1/2".

8. Screw the adjusting shaft into the adjusting shaft retainer all the way in as shown in Fig. 1.

9. Install the adjusting retainer and shaft onto the high-speed spring plunger. Turn down the adjusting retainer against the idle speed adjusting lock nut.

10. Install the adjusting coupling and spring housing after the governor adjustments (Section 14.3.3) have been performed.

Install Governor

Install the governor as outlined in Section 2.7.1 or 2.7.1.1, then connect the manual control flexible shaft to the governor spring housing (Fig. 1).

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

Adjust the governor as outlined in Section 14.3.3.

AIR OPERATED GOVERNOR

Remove Governor From Engine

1. Disconnect the air controls from the governor spring housing.

2. Remove the governor following the same procedures outlined in Section 2.7.1 or 2.7.1.1.

Disassemble Governor

The air operated variable low-speed limiting speed governor is similar to the limiting speed governor with the exception of the spring housing and its components. Therefore, disassemble the governor as outlined in Section 2.7.1 or 2.7.1.1, then disassemble the spring housing and its components (Fig. 3) as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.

2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket. Discard the gasket.

3. Loosen the 5/16"-24 idle speed jam nut and remove the idle speed adjusting screw, seal ring and nut as an assembly. Discard the seal ring.

4. Hold the 1/2"-20 jam nut on the high-speed spring plunger with a wrench and unscrew the air cylinder cap, retainer ring, pin, piston, air cylinder and seal ring as an assembly from the end of the high-speed spring plunger.

   a. Disengage the retainer ring from the air cylinder and remove the air cap and piston from the air cylinder.

   b. Remove the seal ring from the piston. Discard the seal ring.

5. Unscrew the high-speed spring retainer lock nut and remove the high-speed spring retainer, plunger and spring along with the low speed spring plunger, inner and outer springs and low-speed spring cap as an assembly from the governor housing.

6. Remove the high-speed spring retainer and spacer assembly and spring from the high-speed spring plunger. Remove the low-speed spring cap from the opposite end of the high-speed spring plunger and remove the low-speed spring plunger along with the inner and outer low-speed springs.

Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, then inspect them as outlined in Section 2.7.1 or 2.7.1.1.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

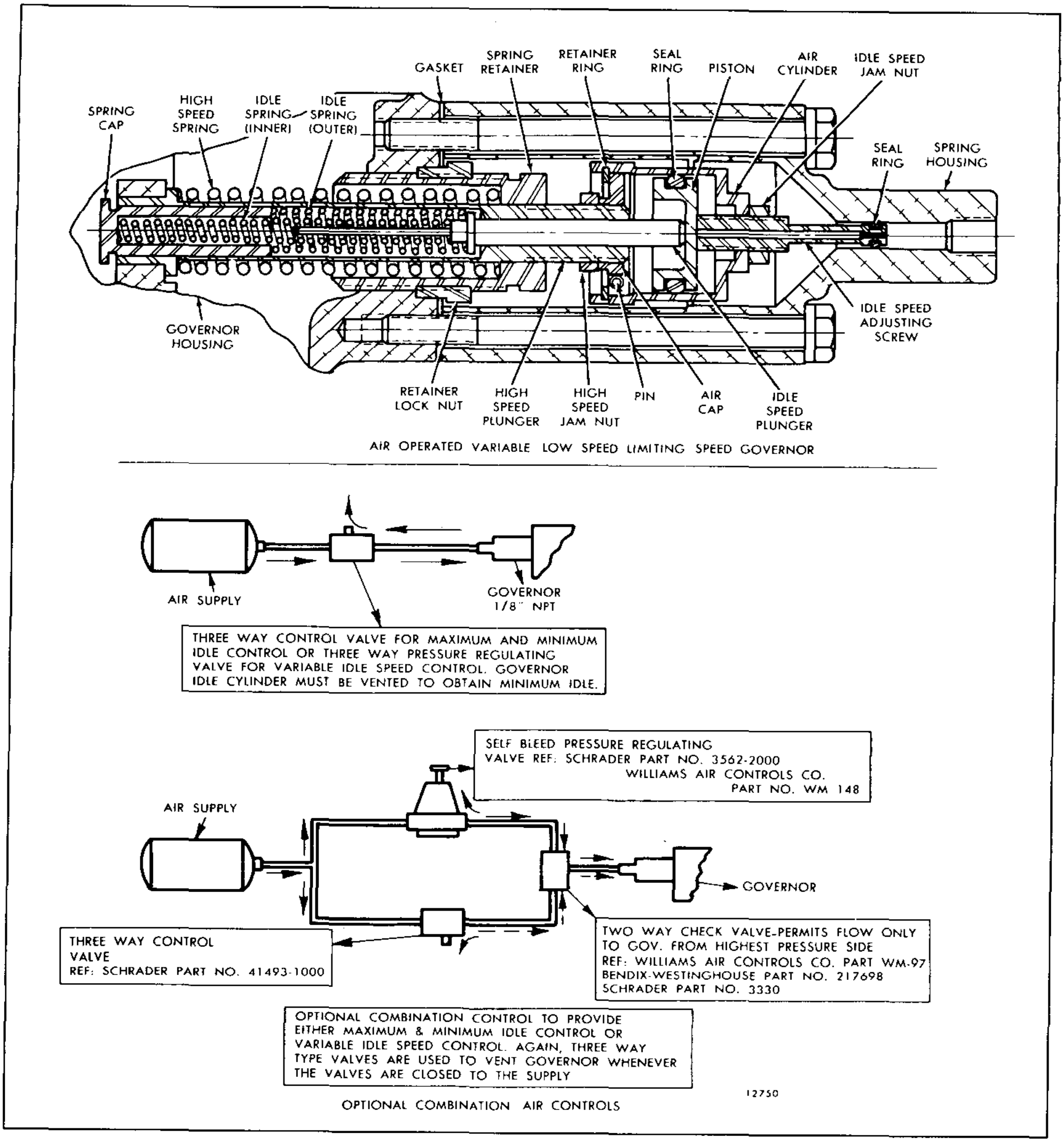


Fig. 3 – Air Operated Variable Low Speed Limiting Speed Governor and Air Controls

Assemble Governor

During assembly, lubricate all spring housing components with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1 or 2.7.1.1, then assemble the spring housing and components (Fig. 3) as follows:

1. Thread the spring retainer lock nut approximately 1–1/2" onto the high–speed spring retainer.
2. Place the high–speed spring on the high–speed spring plunger.
3. Insert the high–speed spring and plunger assembly in the high–speed spring retainer.
4. Insert the low–speed spring plunger into the high–speed spring plunger.
5. Place the inner and outer springs in the lower end of the high–speed spring plunger, over the low–speed spring plunger.
6. Install the low–speed spring cap over the end of the inner low–speed spring and into the end of the high–speed spring plunger and install the assembly in the governor housing. *Place the new spring housing gasket in position before installing the assembly.*
7. If removed, thread the 1/2"–20 high–speed spring jam nut approximately 1/2" onto the threaded end of the plunger.
8. Place a new seal ring on the piston and assemble the piston and air cap in the air cylinder. Secure them in the air cylinder with the retainer ring.
9. Screw the air cylinder assembly onto the high–speed spring plunger and against the high–speed spring plunger and jam nut.
10. Place a new seal ring on the idle adjusting screw and install the adjusting screw and jam nut in the air cylinder.
11. Install the spring housing after the governor adjustments (Section 14.3.3) have been performed.

    Be sure and lubricate the bore of the spring housing with grease as stated previously.

Install Governor

Install the governor as outlined in Section 2.7.1 or 2.7.1.1, then connect the air controls to the governor spring housing (Fig. 3).

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

Adjust the governor as outlined in Section 14.3.3.

LIMITING SPEED MECHANICAL GOVERNOR (FAST IDLE CYLINDER)

6V–53 VEHICLE ENGINE

The double–weight limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Fig. 1). An engine shutdown air cylinder, if used, is also mounted on the governor cover.

For operation and adjustment of the fast idle air cylinder, refer to Section 14.3.4.

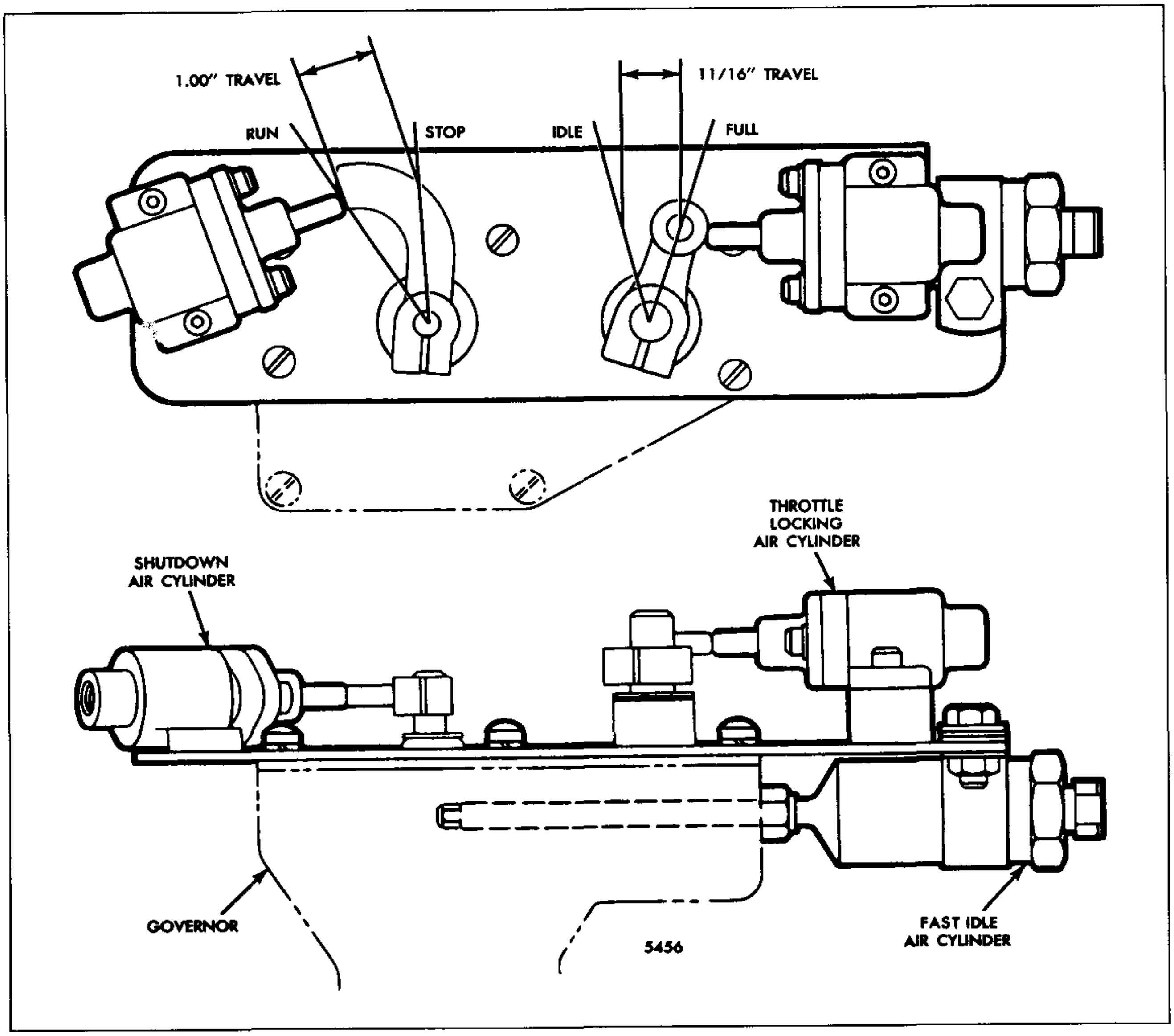


Fig. 1 – Governor with Fast Idle Cylinder

Lubrication

The governor is lubricated in the same manner as the limiting speed governor (Section 2.7.1.1).

Check Governor Operation

Governor difficulties should be checked in the manner outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

Remove Governor

1. Release any air in the system and disconnect the air hoses from the air cylinders.
2. Remove the governor by following the procedure outlined in Section 2.7.1.1.

Disassemble Governor

1. Disassemble the governor as outlined in Section 2.7.1.1.
2. Refer to Fig. 2 and disassemble the fast idle cylinder as follows:
   a. Pull the plunger out of the buffer spring and cylinder.
   b. Clamp the air cylinder in a vise equipped with soft jaws.
   c. Apply pressure on the end of the air inlet plug and remove the plug retaining ring from the groove in the air cylinder.
   d. Pull the air inlet plug and seal ring assembly from the air cylinder. Remove the seal ring from the groove in the plug.
   e. Insert a 3/32" diameter steel rod in the plunger opening in the air cylinder and push the piston, seal ring, dual idle spring and spring follower out of the air cylinder as an assembly. Then remove the air cylinder spring from the cylinder.

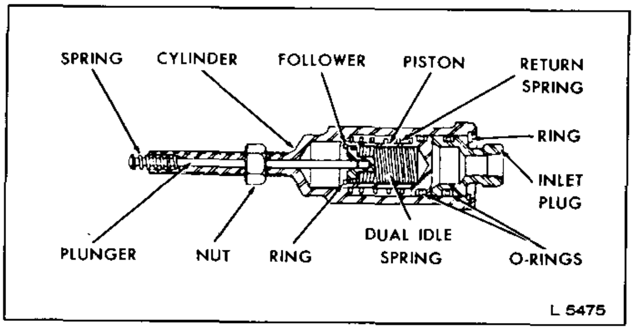


Fig. 2 – Fast Idle Air Cylinder

   f. Remove the seal ring from the groove in the piston. Apply pressure on the spring follower and remove the follower retaining ring from the groove in the piston. Remove the follower and spring.

Inspection

Wash all of the governor components in clean fuel oil and dry them with compressed air. Then inspect them as outlined in Section 2.7.1.1.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the fast idle air cylinder components for wear or any defects. Replace worn or damaged parts.

Assemble Governor

1. Assemble the governor as outlined in Section 2.7.1.1.
2. Assemble the fast idle cylinder as follows:
   a. Refer to Fig. 2 and insert the dual idle spring inside of the fast idle air cylinder. Place the spring follower, with the small diameter end down, inside of the spring. Apply pressure on the spring follower and compress the spring enough to expose the retaining groove. Then install the retaining ring in the groove.
   b. Install a new seal ring in the groove in the piston. Then install the air cylinder spring over the small diameter end of the piston.
   c. Lubricate the seal ring on the piston with engine oil. Then insert the piston and spring assembly, with the small diameter end of the piston first, straight into the air cylinder spring seats on the shoulder in the cylinder.
   d. Install a new seal ring in the groove of the air cylinder air inlet plug.
   e. Lubricate the seal ring with engine oil. Then insert the air inlet plug straight into the air cylinder and against the piston.
   f. Clamp the air cylinder in a vise equipped with soft jaws. Apply pressure on the end of the air inlet plug and compress the spring enough to expose the retaining ring groove. Then install the retaining ring.
   g. If removed, thread the lock nut on the air cylinder. Then insert the plunger through the buffer spring and into the air cylinder.
3. Install the fast idle air cylinder assembly in the governor housing buffer screw hole.

Install Governor

1. Install the governor on the engine as outlined in Section 2.7.1.1.
2. Install the throttle locking and engine shutdown air cylinders.
3. Connect the air hoses to the air cylinders.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

4. Adjust the governor as outlined in Section 14.3.4.

LIMITING SPEED MECHANICAL GOVERNOR

(Variable High-Speed)

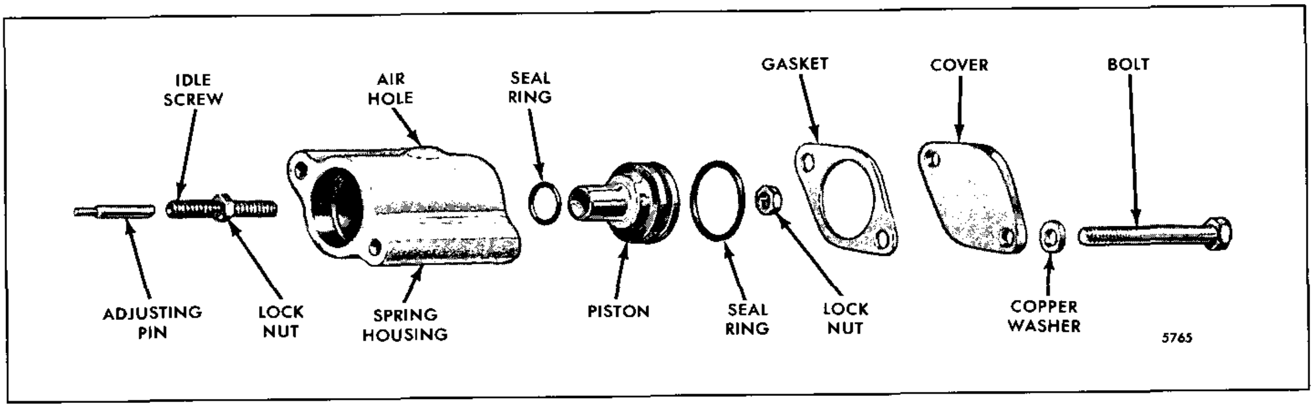


Fig. 1 – Air Operated Variable High Speed Limiting Speed Mechanical Governor Components

The air operated variable high speed limiting speed mechanical governor is provided for highway vehicle applications where the same engine powers both the vehicle and auxiliary equipment, for unloading bulk products (such as cement, grain or liquids) and where a variable speed range is desired during auxiliary constant speed operation.

Operation

The idle speed range for these governors is the same as for the standard limiting speed governors. The normal no–load speed range is the same as for the standard limiting speed governor. A variable high speed limiting governor will control engine RPM from any normal no–load speed down to near idle speed. Also, in addition to the high speed control kit, a regulated air supply and an air cylinder to move the throttle to the wide open throttle position is required.

Install Control Housing

Without disturbing the engine tune–up, install a high speed control housing assembly on a standard limiting speed governor having a long spring pack, as follows (Fig. 1):

1. Loosen the two bolts and copper washers and remove the spring retainer housing.

2. Remove the idle speed adjustment screw and replace it with the longer high speed control idle speed screw and reset the idle speed RPM to the previous setting.

   If the governor has the former one piece idle speed screw, replace it with the current idle speed pin and long screw.

   The engine tune–up procedure for the high speed control governor is the same as stated in Section 14.3 except the idle speed adjustment is made, using the longer idle speed screw.

3. Assemble the high speed control housing as follows:

   a. Install the small ring in the spring housing and the large seal ring on the piston.

   b. Lubricate the piston and inside of housing with engine oil and install the piston in the housing.

4. Slide the housing and piston assembly over the spring retainer and idle speed screw.

5. Install the idle screw self–locking nut and make the following adjustments:

   a. Place a .010″ feeler gage between the VHS housing gasket and the main governor housing.

   b. Adjust the elastic stop nut, while holding the idle screw stationary, until a slight drag is felt on the shim (Fig. 2). This adjustment is made easily with Tool J 28598–A.

   c. Remove the shim.

6. Install the gasket and either flat or tamper–resistant cover with two copper washers and two 5/16″–18 x 4 1/2″ bolts (flat cover). Tighten bolts.

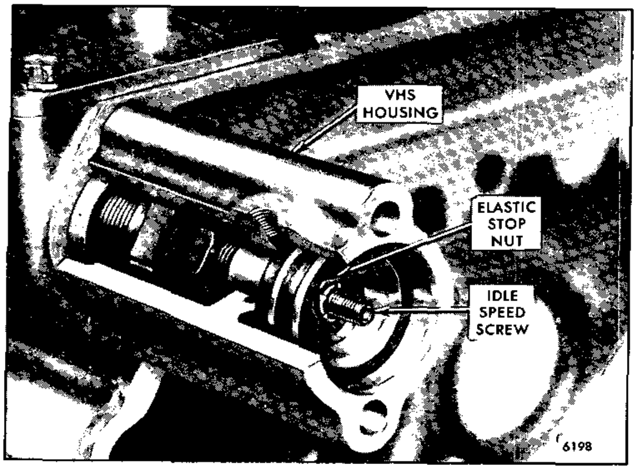


Fig. 2 – Adjust Elastic Stop Nut Using Tool J 28598–A

Install the air cylinder on the governor cover so that it does not interfere with the throttle linkage when no air pressure applied and moves the speed control lever to the wide open throttle position with full air pressure applied (Fig. 3).

Supply air should only be taken from the accessory air supply. At no time should supply air be taken from the service brake system. However all air supply components should be plumbed and mounted in compliance with the recommendations for the air brake system. Both air cylinders must be vented to insure rapid disengagement.

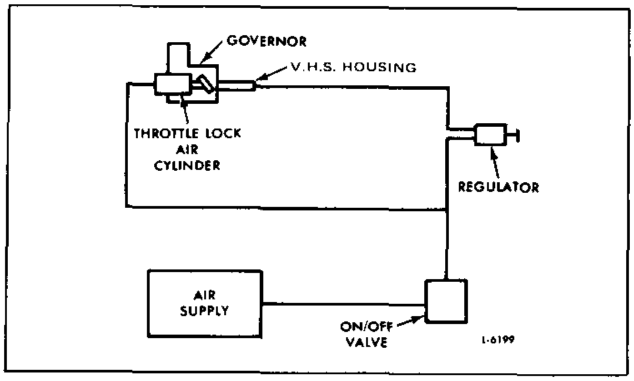


Fig. 3 – Schematic Drawing of Limiting Speed Mechanical Governor (Variable High Speed)

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the *no fuel* postion when the governor stop lever is placed in the *stop* position. Engine over–speed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An over–speeding engine can result in engine damage which could cause personal injury.

VARIABLE SPEED MECHANICAL GOVERNOR

6V ENGINE

The variable speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idling speed.
2. Limits the maximum no load speed.
3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

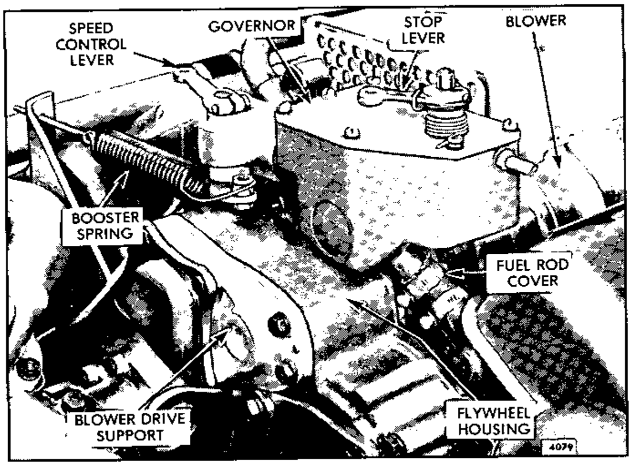


Fig. 1 – Governor Mounting

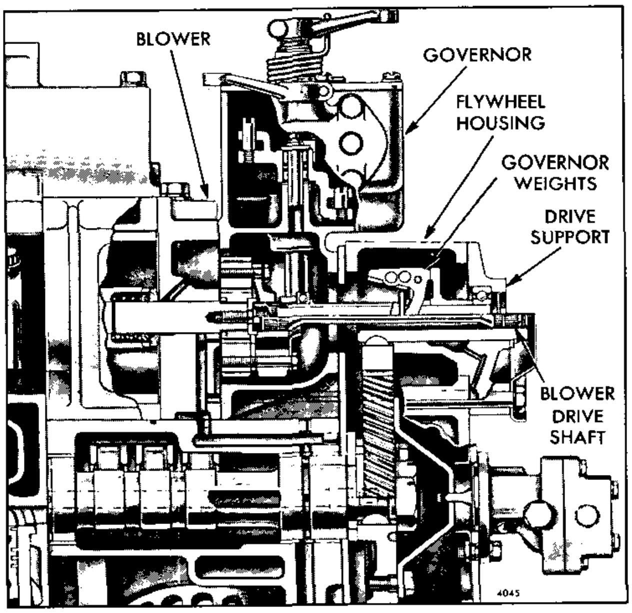


Fig. 2 – Governor and Drive

The governor is mounted between the engine blower and the flywheel housing. One end of the governor weight shaft is splined to a drive plate attached to the driven blower timing gear to provide a means of driving the governor. The other end of the governor weight shaft is supported on a bearing in the blower drive support (Fig. 2).

The governor consists of a cover and lever assembly, governor control housing, variable speed spring housing and shaft, and governor weight and shaft assembly with a single pair of weights.

For certain applications, a heavy–duty governor is provided. This governor has two pair of weights, one high speed spring (former governor has two high speed springs), a heavier operating shaft and related components, larger bearings and a blower drive support which has a larger bore to admit the larger weight shaft bearing.

The new nylon retainer bearing is completely interchangeable with the current steel retainer bearing. However, only the new bearing will be serviced.

Operation

Two manual controls are provided on the governor; a stop lever and a speed control lever. In its normal position, the stop lever holds the fuel injector racks near the full–fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

Current governor covers include a longer serrated shutdown shaft and lever to provide positive clamping between the serrated levers and shafts. The longer shaft also has provisions for a yieldable speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever bears against the variable speed spring plunger, while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

Fig. 3 – Removing or Installing Blower Drive Support

Fuel rods are connected between the control link operating lever and each injector control tube lever. A vertical pin in the differential lever engages the slot in the control link lever fork. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no fuel position and held there until the engine stops.

Adjustment of the governor is covered in the *Engine Tune–Up* Section.

Lubrication

The governor is lubricated by a spray of pressurized lubricating oil from the blower rear end plate to the blower timing gears which distribute this oil to various parts of the governor. Oil splash from the gear train provides lubrication of the governor weights and shaft. Excess oil overflows into the gear train compartment and returns to the crankcase.

The governor weight shaft bearing, in the heavy–duty governor, is lubricated by oil flowing under pressure through a drilled passage from the cavity surrounding the blower gear drive shaft to the bearing bore in the blower drive support.

Remove Governor From Engine

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If, after performing these checks, the governor fails to control the engine properly, it should be removed and reconditioned. Since the governor is mounted between the blower and the flywheel housing, it must be removed along with the blower as outlined below.

1. Disconnect the throttle control rod and the booster spring from the speed control lever (Fig. 1).
2. Disconnect the retracting spring from the stop lever or cover screw.
3. Remove the attaching screws and lock washers and lift the cover and lever assembly and the gasket from the governor housing.
4. Loosen the two attaching bolts and lock washers and withdraw the variable speed spring housing and lever assembly and gasket from the governor.
5. Remove the spring retainer, shims, variable speed spring(s), stops and spring plunger.
6. Loosen the hose clamps and slide the hoses back on the fuel rod covers.
7. Remove the valve rocker cover from each cylinder head.
8. Disconnect the lower fuel rod from each injector control tube lever and also from each upper fuel rod.
9. Remove the threaded pins which connect the upper fuel rods to the control link lever. Remove the fuel rods.
10. Remove the blower drive support assembly (Fig. 3) and the blower drive shaft as outlined in Section 3.4. The governor weights, carrier, riser tube and bearing assembly, and weight shaft will be removed with the blower drive support.
11. Remove the governor weight shaft and carrier assembly from the blower drive support, using pry bars if necessary.
12. Remove the blower and governor housing assembly as outlined in Section 3.4.
13. Remove the six bolts and lock washers which attach the governor housing to the blower rear end plate. Studs and nuts were used in place of one or two of the bolts on early units. Remove the governor housing and gasket.

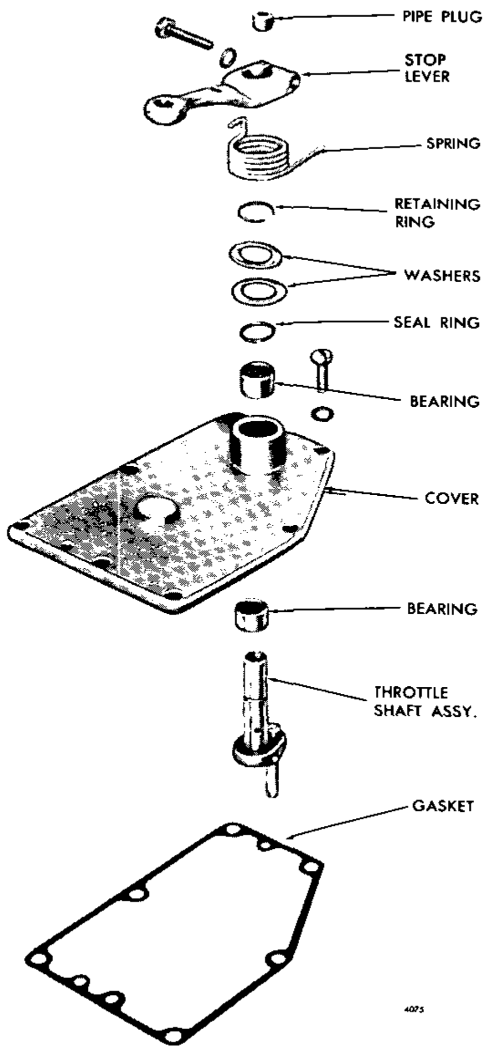


Fig. 4 – Governor Cover Details and Relative Location of Parts

Disassemble Governor Cover

1. Loosen the governor stop lever retaining bolt and remove the lever from the shaft. Remove the lever retracting spring.

2. Remove the retaining ring and the two seal retaining washers. Withdraw the throttle shaft from the cover (Fig. 4).

3. Remove the seal ring from the cover.

4. At this stage of disassembly, wash the cover assembly thoroughly in clean fuel oil and inspect the bearings or bushing for wear or damage. If the bearings (or bushing) are satisfactory for further use, removal is unnecessary.

5. If the bearings (or bushing) are to be removed, place the governor cover with the inner face down on an arbor press. Place a hollow spacer between the cover and the bed of the press (Fig. 5). Place the bearing remover J 21967–01 on top of the upper bearing (or bushing) and press both bearings (or bushing) out of the cover.

Disassemble Governor Spring Housing

If the bearings or lever require replacement, disassemble the spring housing as follows:

1. Loosen the clamp bolt and remove the speed control lever from the shaft. Remove the Woodruff key.

2. Loosen the clamp bolt and remove the booster spring lever, if used. Remove the Woodruff key.

3. Remove the plain washer and seal ring. If a booster spring lever is used, a washer an

4. On current governors, remove one screw and lock washer and remove the spring housing cover and gasket. Then remove the set screw from the spring lever.

   On former governors, remove the pipe plug from the housing and, working through the opening, remove the set screw from the spring lever.

5. Support the spring housing in an arbor press. Use a brass rod to press the shaft, bearing and plug (if used) from the housing.

6. Remove the spring lever assembly.

7. Press the second bearing from the housing.

Disassemble Governor Housing

1. Remove the governor buffer screw and spring.

2. Remove the spring pin and washer from the control link lever pin (Fig. 7) and withdraw the control link lever and washer.

3. If the bearings require replacement, support the control link lever on a sleeve placed on the bed of an arbor press. Then press the bearings out of the lever with tool J 8985 (Fig. 8).

4. Remove the spring pin and washer from the pin in the operating shaft lever and remove the differential lever.

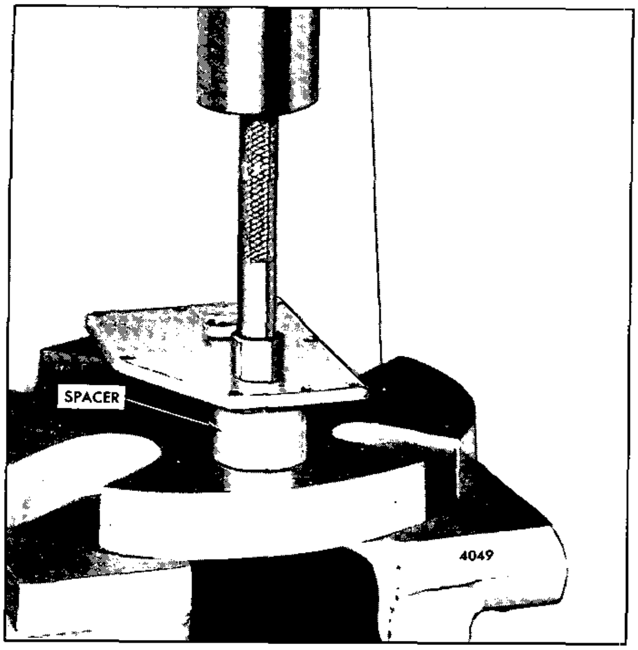


Fig. 5 – Removing Governor Cover Bearings Using Tool J 21967-01

5. Remove the plug at the bottom of the governor housing.

6. Remove the set screws, if used, from the governor operating fork.

7. Remove the operating shaft upper bearing retaining screw and washer.

8. Remove the operating shaft lower bearing by placing the inverted governor housing on the bed of an arbor press; use wood blocks to prevent damage to the dowel pins in the housing. Press on the shaft, using a rod small enough to pass through the bearing, until the bearing is free of the shaft. Then withdraw the bearing.

9. Place an end wrench between the operating fork and the governor housing and a rod on the end of the operating shaft. Then press the shaft out of the fork (Fig. 9).

10. Withdraw the operating shaft, operating shaft lever and bearings. Also withdraw the fork spacer, if a heavy-duty governor is being disassembled.

11. Press the upper bearing and operating shaft lever from the shaft.

Disassemble Governor Weights And Shaft

1. Remove the retaining rings from the governor weight pins (Fig. 10). Then drive the pins out of the carrier and the weights. Remove the governor weights

2. Press the governor weight carrier from the shaft (Fig. 11).

3. Slide the governor riser and bearing assembly from the shaft. Do not remove the bearing since the bearing and riser are serviced only as an assembly.

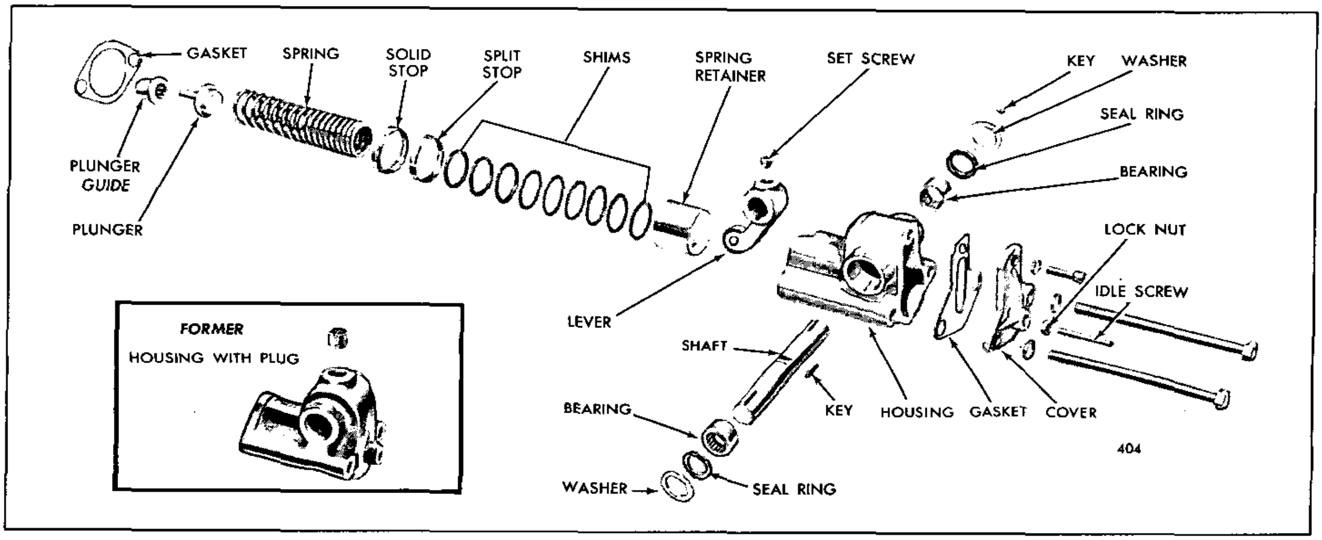


Fig. 6 – Variable Speed Spring Housing Assembly

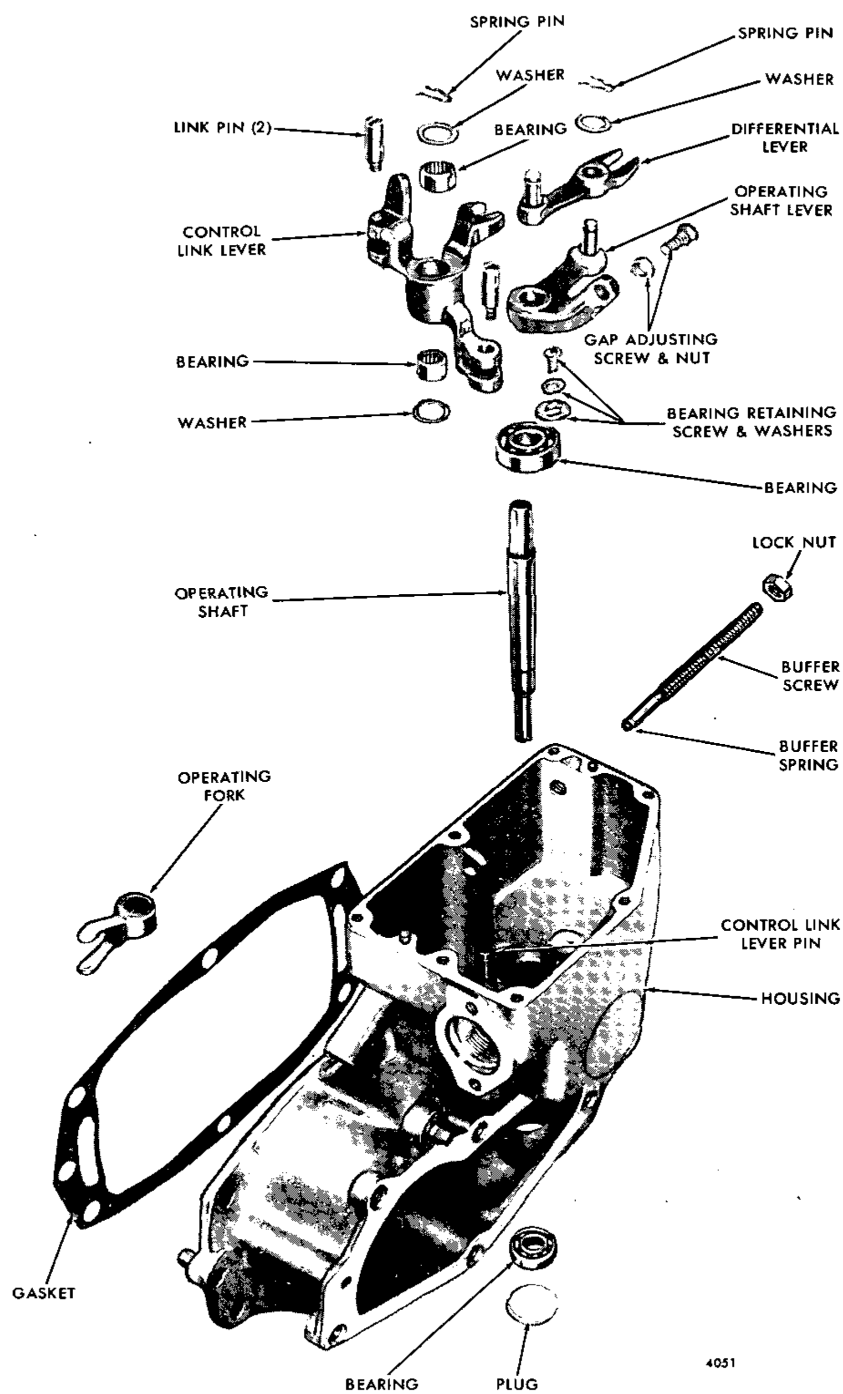


Fig. 7 – Governor Housing Details and Relative Location of Parts

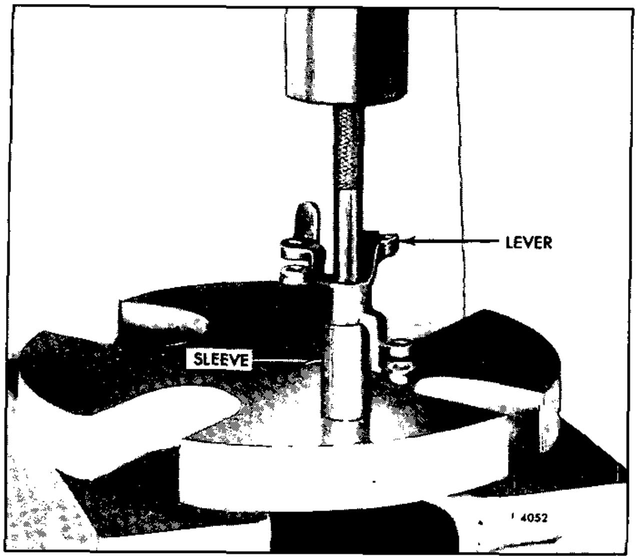


Fig. 8 – Removing or Installing Control Link Lever Bearings Using Tool J 8985

Disassemble Blower Drive

1. Remove the snap ring and the thrust washer from the blower drive gear shaft (Fig. 12). Slide the shaft and gear from the blower drive support.

2. Press the drive gear from the shaft and remove the key.

3. Tap the governor weight shaft bearing from the blower drive support. If the bearing is a tight fit, drive the plug from the support and, using a spacer against the outer race of the bearing, press or tap the bearing from the support.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

NOTICE: Do not use a solvent-base paint stripper or carbon remover when cleaning a nylon race bearing. The nylon can be seriously damaged by these compounds.

Inspect all bearings. Replace corroded or pitted bearings. Revolve ball bearings slowly by hand. Replace bearings which indicate rough or tight spots.

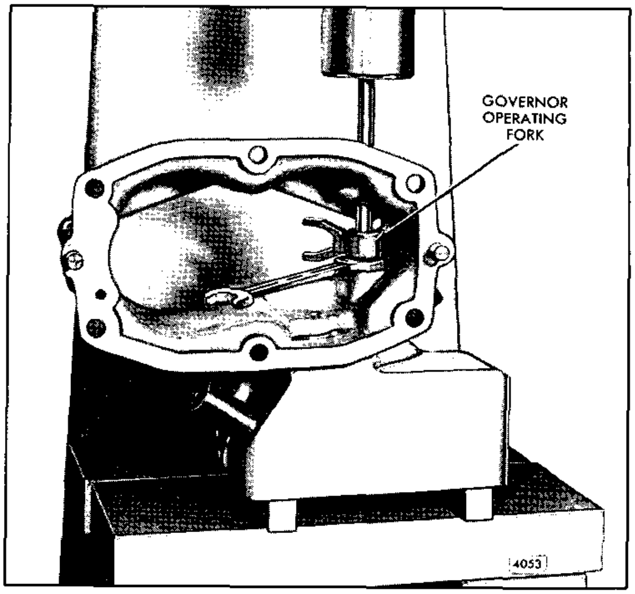


Fig. 9 – Removing Governor Operating Fork

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and thrust bearing assembly.

Inspect the control link lever, needle bearings and control link lever pin for wear. Replace worn parts. If a new control link lever pin is required, remove the old pin and press the new pin in the governor housing; the pin must project 1.055" to 1.060" above the boss in the housing.

Examine the governor weight carrier pins for wear.

Examine the variable speed spring lever roller and pin for excessive wear. The current roller type bearing rides on a hardened bearing pin which is a press fit in the spring lever and is staked at three places on both sides. The former ball type bearing (with two washers) rides on a soft bearing pin that is swagged at both ends to retain the bearing in the spring lever.

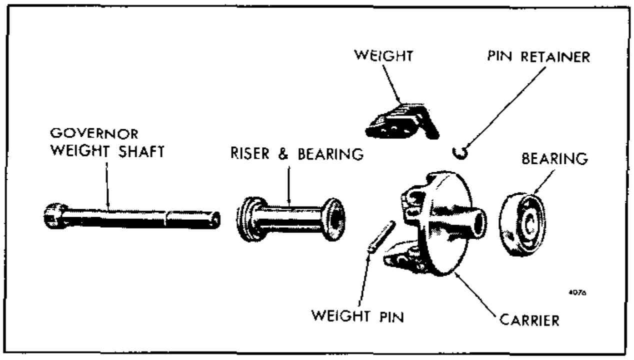


Fig. 10 – Governor Weight Details and Relative Location of Parts

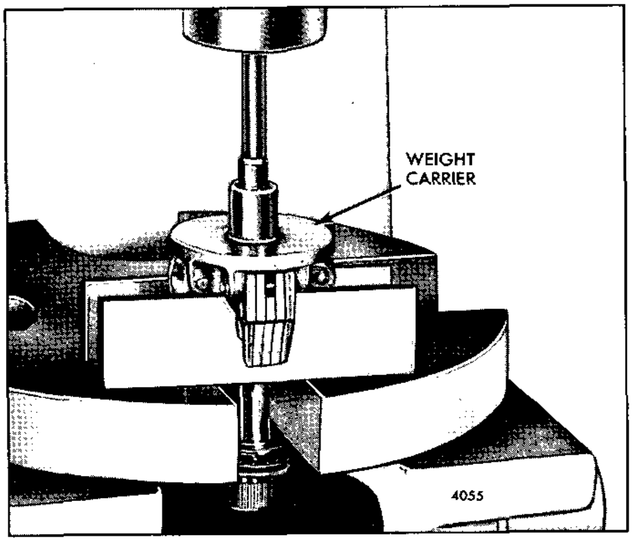


Fig. 11 – Removing Shaft from Weight Carrier

Examine the variable speed spring plunger, guide and spring retainer for wear or score marks. If the retainer or plunger are scored slightly, clean them up with crocus cloth. Replace the retainer, plunger and guide if scored excessively.

Check the serrations on the governor weight shaft and the drive plate on the blower timing gear for wear. Replace worn parts.

Assemble Governor Cover

Refer to Figs. 4 and 13 and assemble the governor cover as follows:

1. Place the cover, with the inner face down, on the bed of an arbor press. Start a needle bearing straight into the bearing bore of the cover, with the number side of the bearing up. Then. insert the installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover.

2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Place a flat washer over the pilot end of tool and insert the tool in the bearing. Press the bearing in until the washer contacts the cover.

   NOTICE: The bushing, used in certain governor covers, is not serviced. For service, install two needle bearings. To avoid bearing damage, do not use impact tools to install needle bearings.

3. Pack the needle bearings with grease. Then slide the governor throttle shaft assembly through the bearings, with the fulcrum lever pin seated in the slot on the underside of the cover.

4. Install a new seal ring on top of the upper bearing. Then install two seal retaining washers and lock them in place with the retaining ring. *A .0329" thick, .312" I.D. x .672" O.D. seal ring back–up washer is used in place of the lower washer on certain governor covers.*

5. If a torsion–type stop lever retracting spring is used, place it over the cover hub with the hooked end up (Fig. 4). Then place the governor stop lever on the shaft and secure it with a bolt and lock washer.

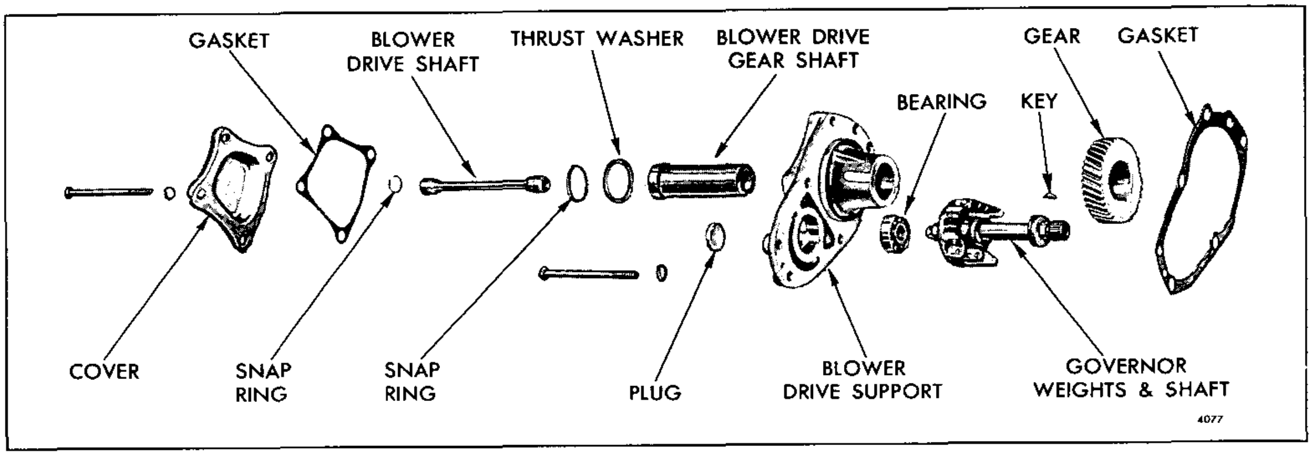


Fig. 12 – Blower Drive Support Details and Relative Location of Parts

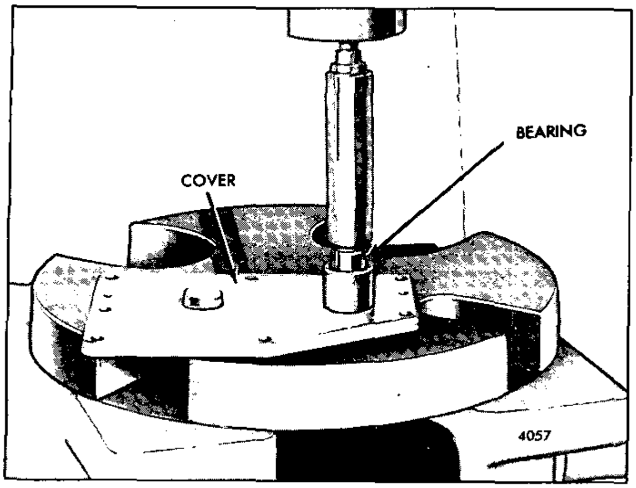


Fig. 13 – Installing Governor Cover Bearings Using Tool J 21068

Assemble Governor Spring Housing

1. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right hand side of the spring housing as viewed in Fig. 6.

2. Install the needle bearing pilot rod J 9196–2 in the installer body J 9196–1 and secure it in place with the retaining screw.

NOTICE: To avoid bearing damage do not use impact tools to install needle bearings.

3. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing. When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

4. Install the current roller type bearing and pin in the spring lever. Press the pin below the surface of the lever and stake at three places on both sides of the lever. The former ball type bearing (with two washers) is swagged at both ends to retain the bearing in the spring lever.

5. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

6. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

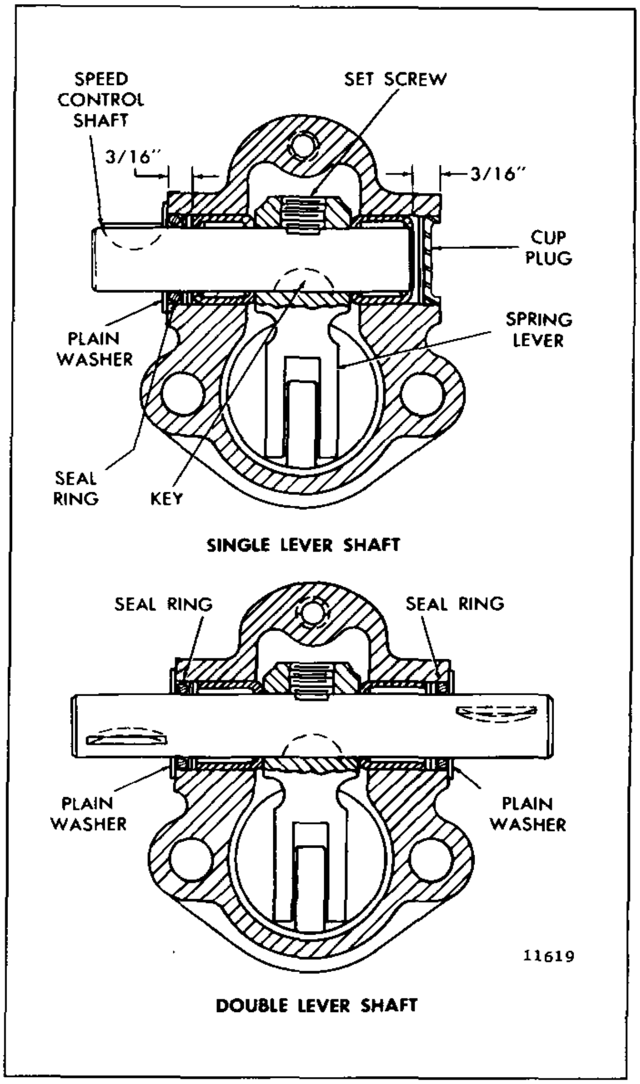


Fig. 14 – Governor Variable Speed Spring Housing

7. Insert the correct end of the (single or double lever type) speed control lever shaft, Fig. 6, through the bearing bore in the side of the spring housing, opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

8. Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.

9. Place the second shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

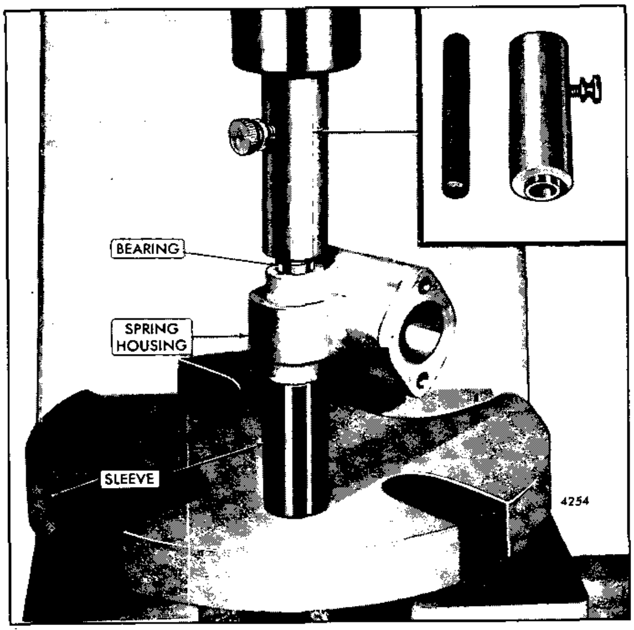


Fig. 15 – Installing Speed Control Shaft Bearings In Spring Housing Using Tool J 9196

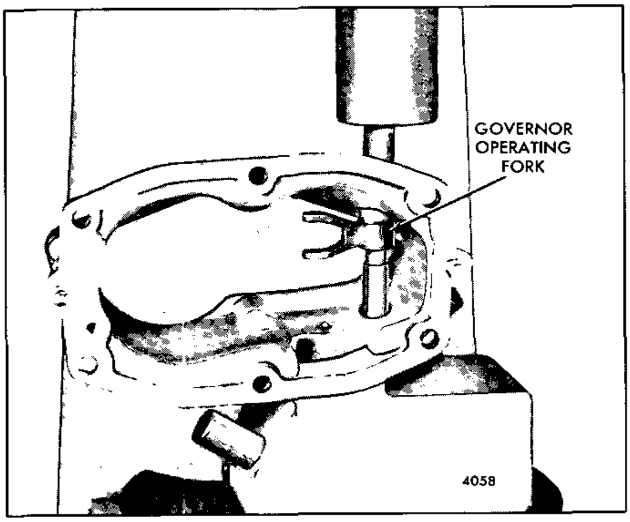


Fig. 16 – Installing Governor Operating Fork on Shaft

10. Remove the bearing pilot rod J 9196–2 from the installer body J 9196–1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing.

11. If a single lever shaft was installed in the spring housing, apply a thin coat of sealing compound to the outside diameter of the cup plug. Start the cup plug straight in the bearing bore in the housing, then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press and press the cup plug in flush with the outside face of the housing.

12. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 5–7 lb–ft (7–10 N·m) torque.

13. Stake the edge of the set screw hole with a small center punch and hammer to retain the set screw in the lever. Then install the plug in the spring housing.

14. On a single lever shaft, place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

15. On a double lever shaft, place a seal ring over each end of the shaft and push them into the bearing bores and against the bearings. Place a plain washer over each end of the shaft and against the housing, then install a Woodruff key in the keyway at each end of the shaft.

16. Place the speed control lever(s) on the shaft in its original position. Align the keyway in the lever with the key in the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lock washer.

Assemble Governor Housing

Refer to Fig. 7 and assemble the governor housing as follows:

1. Start the upper operating shaft bearing, number side up, on the end of the shaft. Support the lower end of the shaft on an arbor press. Place a sleeve on the inner race and press the bearing against the shoulder on the shaft. The shaft on the heavy–duty governor has no shoulder; press the bearing approximately .562" from the end of the shaft.

2. Start the operating shaft lever, with the pivot pin up, on the end of the shaft with the flat on the shaft registering with the flat in the lever bore. Use a sleeve to press the lever tight against the bearing. On the heavy–duty shaft, use a rod to press the lever against the bearing until the lever is flush with the end of the shaft.

3. Insert the lever and shaft assembly through the top of the governor housing. On the heavy–duty governor, slide the 2.50" long governor fork spacer on the shaft. Position the operating fork over the lower end of the shaft, with the finished cam surfaces facing toward the rear of the governor (toward the governor drive).

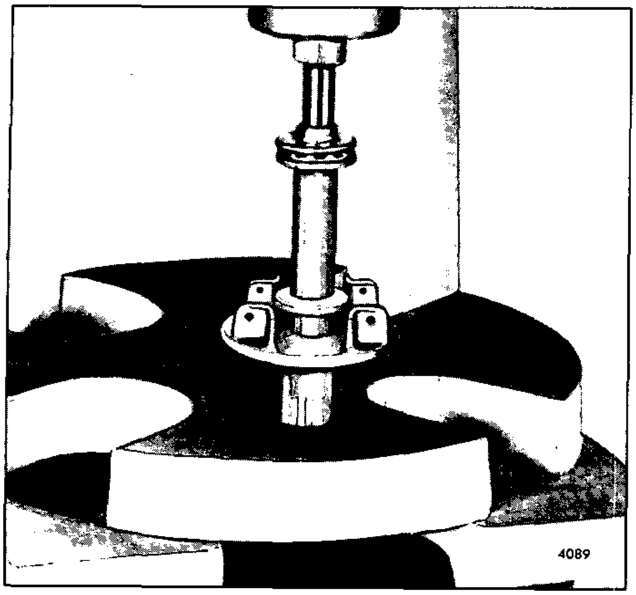


Fig. 17 – Installing Weight Carrier on Shaft Using Tool J 8984

4. Support the operating shaft and governor housing on the bed of an arbor press with the upper end of the shaft resting on a steel block (Fig. 16). Align the flat in the fork with the flat on the shaft, then place a sleeve over the shaft and against the fork. Press the fork tight against the shoulder on the shaft or against the fork spacer. Install the set screw and lock screw, if used, in the fork.

5. Start the lower operating shaft bearing, number side up, on the end of the shaft. Place a sleeve on the outer race and press the bearing against the shoulder in the housing.

6. Lubricate both bearings with engine oil.

7. Apply a good quality sealant around the edge of a new expansion plug and drive it securely in place in the housing. Do not break the housing.

8. Secure the upper operating shaft bearing in place with a retaining screw and flat washer.

9. Place the differential lever over the pivot pin in the operating shaft lever (Fig. 7). Secure the lever with a washer and spring pin.

10. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

11. Support the control link lever on a steel spacer as shown in Fig. 8. Start one bearing, number side up, in the lever. Insert the pilot end of installer J 8985 in the bearing and press the bearing in the lever. Reverse the lever and install the second bearing in the same manner.

12. Place a washer over the end of the control link lever pin in the governor housing. Pack the needle bearings with grease and place the lever, with the tapped ends of the link pin holes down, over the pin in the housing. Secure the lever with a washer and spring pin.

13. Install the buffer screw and lock nut, leaving approximately .750" of the screw extending from the governor housing. The buffer screw lock nut on some earlier governors was an integral part of the governor housing.

Assemble Governor Weights And Shaft

1. Lubricate the governor weight shaft with engine oil, then slide the riser assembly over the shaft with the bearing end toward the serrated end of the shaft. Pack the bearing with grease.

2. Press the shaft into the weight carrier, using tool J 8984 as illustrated in Fig. 17. The tool will properly position the weight carrier on the shaft. However, if a four–weight assembly is used, press the shaft in until it extends .555" to .559" from the weight carrier.

3. Position the weights on the carrier and drive the weight pins in place. Install the retaining rings.

Assemble Blower Drive Support

1. Place the blower drive support, with the inner face up, on the bed of an arbor press. Start the governor weight shaft bearing, number side up, in the bearing bore of the support. Place a sleeve against the outer race and press the bearing firmly against the shoulder in the bearing bore. Attach the bearing retainer (four–weight governor only) with two bolts, nuts and copper washers.

2. Place the steel thrust washer on the end of the blower drive shaft and secure it in place with a snap ring.

3. Lubricate the shaft with engine oil and install it in the drive support.

4. Install the key in the shaft, then place the blower drive support on an arbor press. Lubricate the inner diameter of the blower drive gear and start it straight on the shaft, with the keyway in the gear aligned with the key in the shaft. Place a spacer over the gear and press the gear on the shaft until a .005" feeler gage may just be withdrawn (Fig. 18).

5. Place a support under the inner race of the bearing in the blower drive support and start the weight end of the governor weight shaft into the bearing. Press the shaft in until the shoulder on the shaft contacts the inner race of the bearing. Press the shaft in straight to avoid brinelling the bearing.

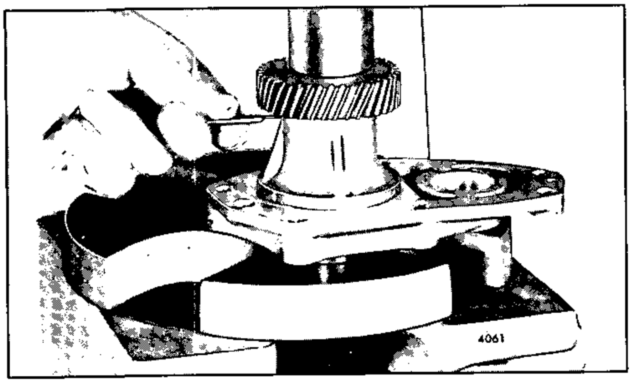


Fig. 18 – Installing Blower Drive Gear on Shaft

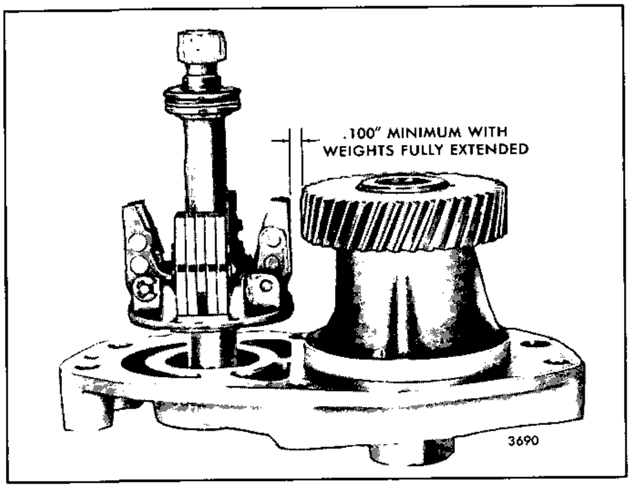


Fig. 19 – Minimum Clearance Between Blower Drive Gear and Governor Weights

6. Apply a good quality sealant on the edge of the cup plug and press the plug in flush with the blower drive support.

7. Check the clearance between the fully extended governor weights and the blower drive gear. This clearance must not be less than .100" (Fig. 19).

INSTALL GOVERNOR

Install the governor on the engine as follows:

1. Attach a new gasket to the governor housing and place the housing against the blower rear end plate. Secure the governor housing to the blower with six bolts and lock washer.

2. Install the blower and governor assembly on the engine as outlined in Section 3.4.

3. Install the blower drive support assembly as outlined in Section 3.4 under *Install Blower on 6V Engine.*

4. Insert the upper fuel rods through the fuel rod covers and hoses and attach the rods to the governor control link lever with link pins which thread into the lever.

5. Attach the lower fuel rods to the injector control tube levers and to the upper fuel rods.

6. Slide the fuel rod cover hoses in place and secure them with hose clamps.

7. Refer to Fig. 6 and install the variable speed spring and housing to the governor as follows:

   a. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and lock washer.

   b. Install the spring plunger guide in the governor housing.

   c. Insert the spring plunger in the plunger guide.

   d. Insert the solid stop in the governor housing.

   e. Place the spring retainer in the spring housing, with the closed end of the retainer against the spring lever. If shims were used, place them inside of the spring retainer. Insert the split stop in the housing and against the spring retainer.

      Be sure to use shims with a .343" inside diameter and a spring retainer with three bleed holes when a two–spring assembly is used. On the one–spring assembly, either spring retainer may be used with shims which have a .750" I.D. However, do not use the .343" I.D. shims with a spring retainer which has only one air bleed hole.

   f. Insert the variable speed spring in the spring retainer with the tightly wound end of the spring against the shims. If a two–spring assembly is used, insert the inner spring inside of the outer spring.

   g. On former governors, insert two bolts with lock washers through the spring housing (through the spring housing cover and spring housing on current governors) and place a new gasket over the bolts and against the housing. On current governors, use copper washers with the two attaching bolts.

   h. Place the spring housing in position against the governor housing, with the spring plunger engaged in the end of the spring (inner spring of the two–spring assembly). Thread the bolts into the governor housing and tighten them.

   i. Install the idle speed adjusting screw and lock nut in the spring housing (former governors) and in the spring housing cover (current governors).

8. Place a new gasket on the governor, then install the governor cover and lever assembly. Be sure the governor control lever assembly enters the slot in the differential lever. Secure the cover to the governor with seven screws and lock washers.

   If a torsion-type stop lever spring is used, a special cover screw is used to hold the spring in place. If a long coil spring is used, the spring retaining bracket is held in place by one of the standard cover retaining screws.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the *governor stop lever is placed in the stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

9. Hook the stop lever spring to the lever and to the spring retaining bracket or the special cover screw.

10. Perform an engine tune-up as outlined in Section 14.

VARIABLE SPEED MECHANICAL GOVERNOR (ENCLOSED LINKAGE)

IN–LINE ENGINES

The variable speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idle speed.
2. Limits the maximum no–load speed.
3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single–weight governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

Operation

Two manual controls are provided on the governor; a stop lever and a speed control lever. In its *normal* position, the stop lever holds the fuel injector racks near the *full–fuel* position. When the engine is started, the governor moves the injector racks toward the *idle speed* position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever bears against the variable speed spring plunger, while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

A fuel rod, connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

To stop the engine, the speed control lever is moved to the *idle speed* position and the stop lever is moved to the *no–fuel* position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.

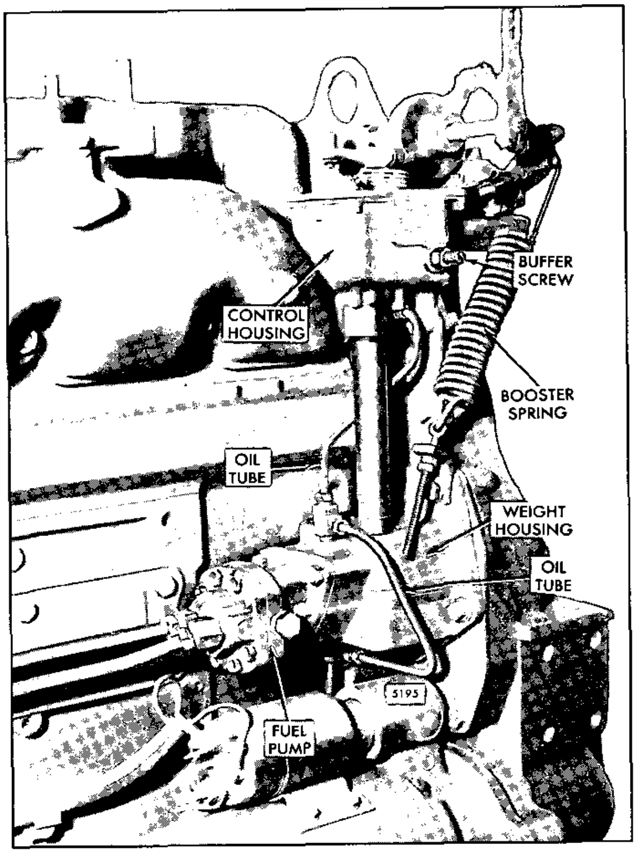


Fig. 1 – Governor Mounting

Lubrication

The governor is lubricated by oil splash from the engine gear train and by an oil line on current engines. Also, to provide increased lubrication to the governor, an oil line with a .400" restricted fitting has been added between the control housing and the weight housing on current engines. The oil passes through the governor weight housing to the shaft and weight assembly. The revolving weights distribute the oil to the various moving parts of the governor. Surplus oil drains from the governor through holes in the governor bearing retainer back to the engine gear train.

Remove Governor from Engine

Check the operation of the governor as outlined in Section 2.7 before removing it from the engine. If the governor fails to control the engine properly after

performing these checks, it should be removed and reconditioned.

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect the throttle rod and the booster spring from the speed control lever.
2. Disconnect the retaining spring from the stop lever. Also, disconnect any linkage attached to the stop lever.
3. Remove the lever retaining spring, governor cover and gasket from the governor housing.
4. Withdraw the two retaining bolts and lock washers and remove the variable speed spring housing and lever assembly and the gasket.
5. Remove the spring plunger, variable speed spring, stops, shims and spring retainer.
6. Loosen the hose clamps between the governor and the cylinder head.
7. Clean and remove the valve rocker cover.
8. Disconnect the fuel rod from the injector control tube lever.
9. Disconnect the fuel lines from the fuel pump. Then, remove the fuel pump from the governor weight housing.
10. Disconnect the lubricating oil tube, if used, from the cylinder block and the governor weight housing.
11. Withdraw the five bolts from the weight housing and the two bolts from the control housing, then remove the governor and the gaskets from the engine.
12. Remove the fuel rod from the differential lever.

Disassemble Governor Cover

1. Loosen the clamping bolt and remove the stop lever from the shaft. Remove the lever retracting spring.
2. Remove the return spring from the underside of the cover (early governors).
3. Remove the retaining ring and seal retaining washer. Withdraw the throttle shaft from the cover (Fig. 2).
4. Remove the seal ring from the cover.

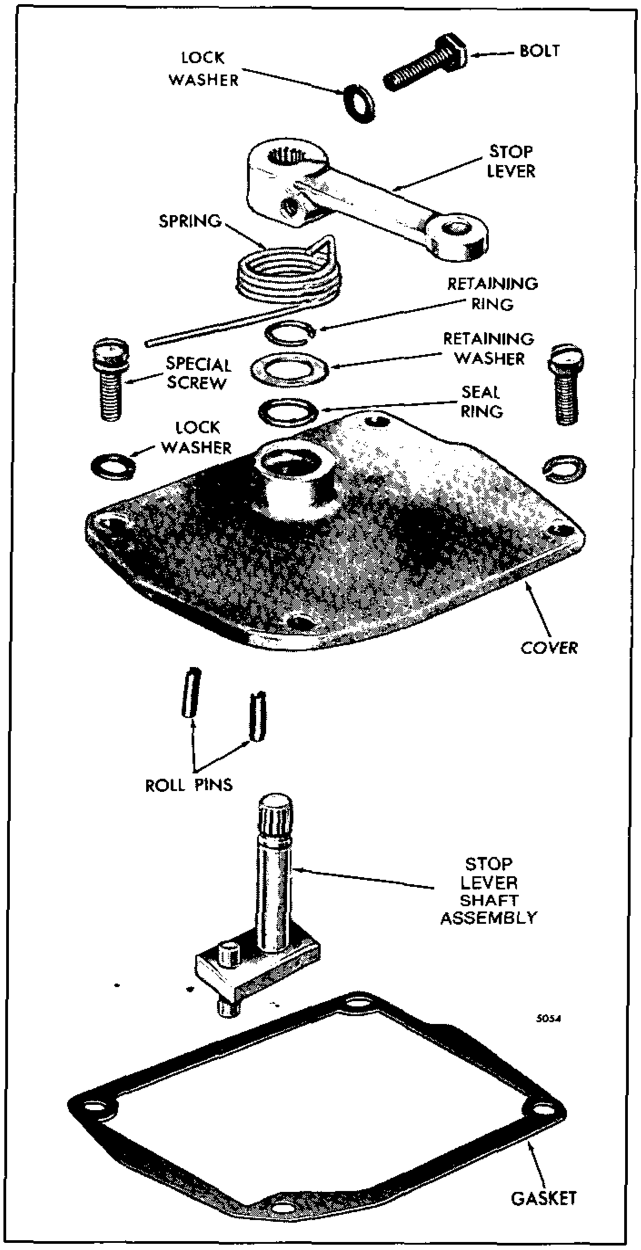


Fig. 2 – Governor Cover Details and Relative Location of Parts

Disassemble Governor Spring Housing

If the bearings or lever require replacement, disassemble the spring housing as follows:

1. Loosen the clamp bolt and remove the speed control lever from the shaft. Remove the Woodruff key.
2. Loosen the clamp bolt and remove the booster spring lever, if used. Remove the Woodruff key.

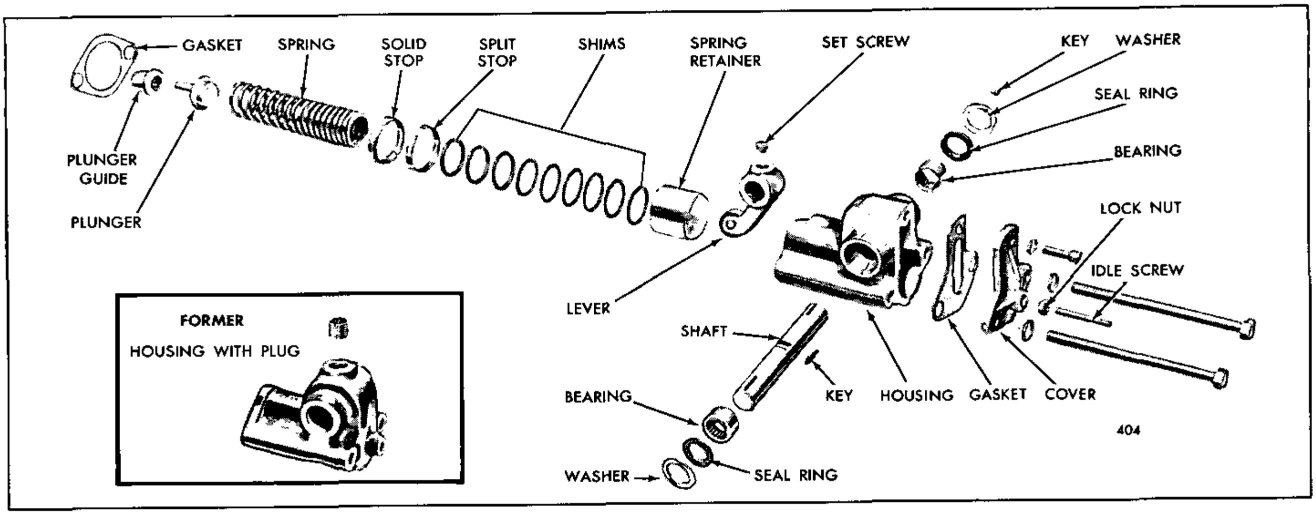


Fig. 3 – Variable Speed Spring Housing and Relative Location of Parts

3. Remove the plain washer and seal ring. If a booster spring lever is used, a washer and seal ring is used at each end of the shaft (Fig. 3).

4. On current governors, remove one screw and lock washer and remove the spring housing cover and gasket. Then, remove the set screw from the spring lever. On former governors, remove the pipe plug from the housing and, working through the opening, remove the set screw from the spring lever.

5. Support the spring housing in an arbor press. Use a brass rod to press the shaft, bearing and plug (if used) from the housing (Fig. 4).

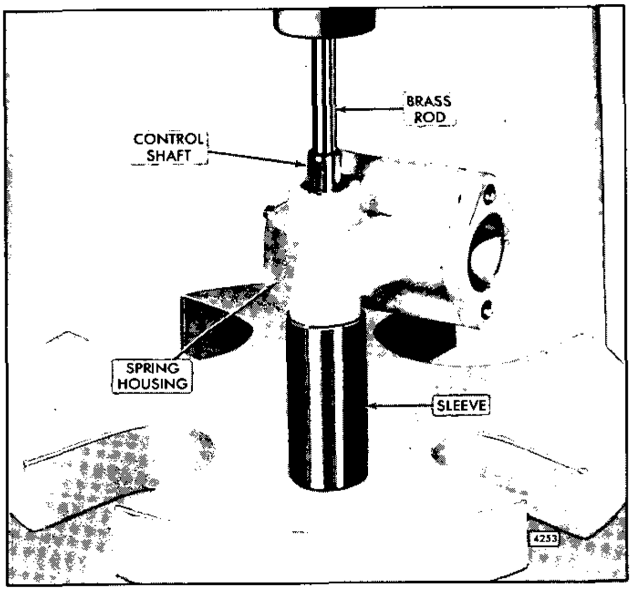


Fig. 4 – Removing Shaft and Bearing from Spring Housing

6. Remove the spring lever.

7. Press the second bearing from the housing.

Disassemble Control Housing

1. Remove the governor drive gear retaining nut. Then, remove the gear, key and spacer from the shaft.

2. Remove the small flat head screw which holds the bearing retainer in place (Fig. 5).

3. Turn the bearing retainer until the large opening is centered over the fork on the governor operating shaft (Fig. 6).

4. Lift up on the weight shaft to provide clearance for a 5/16" electrician's socket wrench. Then, remove the two retaining screws and washers and withdraw the governor operating fork.

5. Remove the shaft and weight assembly from the governor weight housing.

6. Remove the buffer screw and locknut.

7. Remove the upper bearing retaining screw and washer and withdraw the operating shaft and lever assembly from the governor control housing.

8. Insert a rod (approximately 18" long) in the control housing and knock the plug from the bottom of the weight housing.

9. Remove the snap ring and tap the lower operating shaft bearing from the housing.

10. Remove the spring pin and washer from the pin in the operating shaft lever, then remove the differential lever.

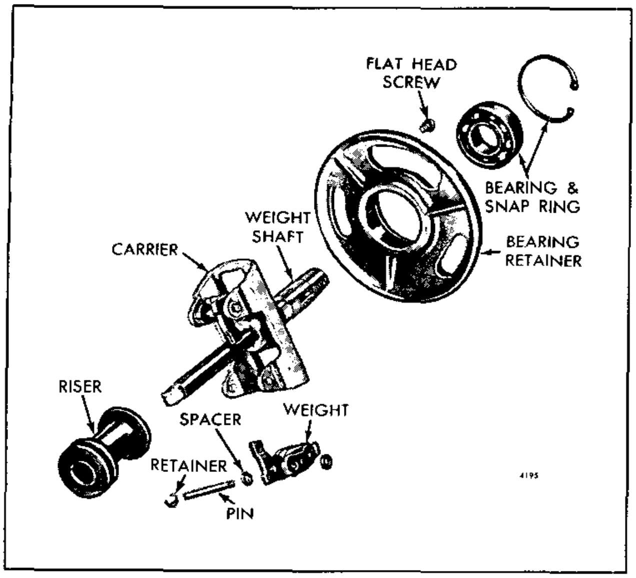


Fig. 5 – Governor Weight Details and Relative Location of Parts

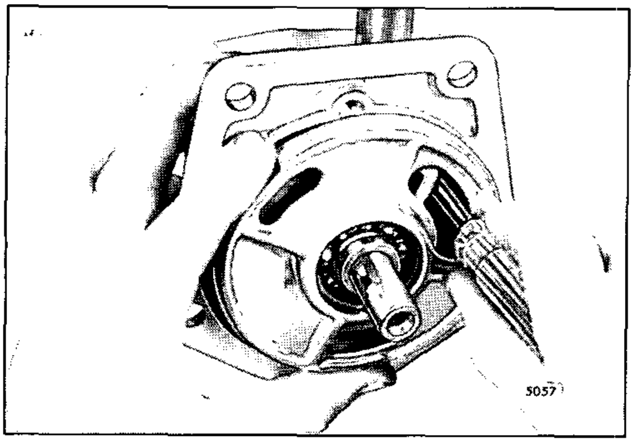


Fig. 6 – Removing or Installing Operating Shaft Fork

11. If necessary, press the bearing and operating shaft lever from the operating shaft.

12. If necessary, disassemble the control housing from the weight housing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer from the weight shaft (Fig. 5).

2. If necessary, remove the snap ring and press the bearing from the retainer.

3. Remove the weight pin retainers and drive the pins out of the carrier and weights. The weight pin hole in the carrier is larger at the side where the pin retainers are located. Remove the weights.

4. Slide the riser and bearing assembly from the shaft. *Do not attempt to remove the bearing since the riser and bearing are serviced only as an assembly.*

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect all of the governor components and replace worn or damaged parts.

The governor cover and throttle shaft have been revised to eliminate the shaft return spring formerly located beneath the cover. An external stop lever retracting spring is used on current governor assemblies. If the cover is to be replaced, install a new current cover and lever assembly and the new spring.

Revolve the ball bearings slowly by hand. Replace bearings which indicate rough or tight spots. Also, replace bearings which are corroded or pitted.

The lower governor drive components have been revised to reduce the clearance between the riser and the weight shaft. With this change, additional lubrication is provided to the governor by an oil tube connected between the oil gallery in the cylinder block and the governor weight housing. When replacing the riser assembly, shaft and carrier assembly or the complete governor assembly, the new *oil tube must be installed to provide adequate lubrication.*

Current engines have an oil line extending from the weight housing to the control housing to provide increased lubrication for the governor components. When replacing a *control housing on a former governor, it will be necessary to* include the oil line and fittings or the tapped hole in the housing must be plugged. Also, the buffer screw assembly with the "Perma–tite" locknut and the copper washers for the spring housing attaching bolts must be used.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and bearing assembly.

Inspect the weight carrier, weights and retaining pins for wear. The current single–weight carrier replaces the former double–weight carrier.

Inspect the fuel pump drive end of the weight shaft. Replace the shaft if the end is worn or rounded.

Inspect the bushing in the weight housing. Replace the bushing if it is worn excessively.

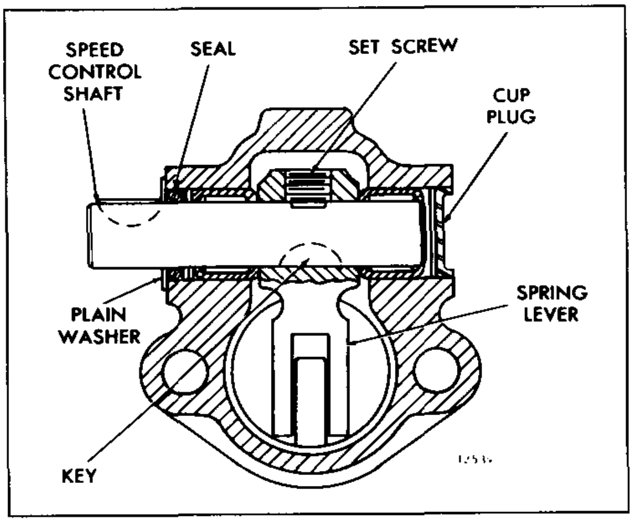


Fig. 7 – Governor Variable Speed Spring Housing

Examine the variable speed spring lever roller and pin for excessive wear. The current roller type bearing rides on a hardened bearing pin which is a press fit in the spring lever and is staked at three places on both sides. The former ball type bearing (with two washers) rides on a soft bearing pin that is swaged at both ends to retain the bearing in the spring lever.

Examine the variable speed spring plunger, guide and spring retainer for wear or score marks. If the retainer or plunger are scored slightly, clean them up with crocus sloth. Replace the retainer, plunger and guide if scored excessively.

The current variable speed spring plunger guide incorporates a replaceable bushing.

Assemble Governor Cover

New mechanical governor cover assemblies with serrated shafts are being used on In–line 53 engines. The new variable speed governor cover assemblies include a new 7/16" diameter serrated stop lever shaft (Fig. 2). The serrations on the shafts ensure positive clamping between the serrated levers and the shafts and prevent any slippage. Four serrations on the stop lever shaft of the variable speed governor are eliminated. This allows certain customers to design a mating lever with missing serrations which will provide a *fixed position* for particular requirements. Levers with missing serrations are not provided. The former and new cover and shaft assemblies are interchangeable on a governor, and only the new assemblies will be serviced. Since the new serrated shafts can be used with the former covers, only the new serrated shafts will be serviced.

1. Lubricate the throttle shaft with engine oil and slide the shaft through the cover, with the pin in the shaft located between the roll pins in the underside of the cover.

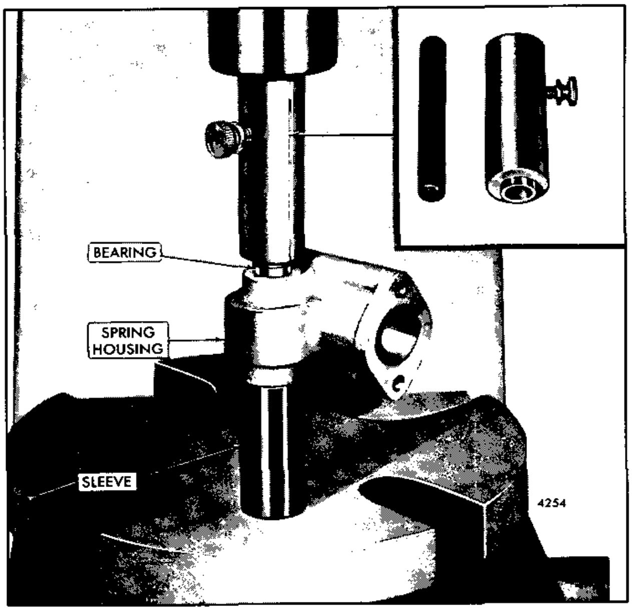


Fig. 8 – Installing Speed Control Shaft Bearings in Spring Housing Using Tool J 9196

2. Install a new seal ring in the counterbore at the top of the cover. Place the seal retaining washer over the shaft and lock the shaft in place with the retaining ring (Fig. 2).
3. If a torsion–type stop lever retracting spring is used, place it over the cover hub with the hooked end up (Fig. 2). Then, place the stop lever on the shaft and tighten the clamping bolt.

The lever retracting spring on early governors was located on the underside of the governor cover and worked against a pin in the throttle shaft assembly. On later governors, the retracting spring is located on top of the cover, connected between the stop lever and a bracket on the cover.

Assemble Governor Spring Housing

1. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then, start one of the bearings, numbered end up, straight in the bearing bore in the right–hand side of the spring housing as viewed in Fig. 7.
2. Install the needle bearing pilot rod J 9196–2 in the installer body J 9196–1 and secure it in place with the retaining screw. Do not use impact tools to install needle bearings.
3. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press and press the bearing in the housing until the shoulder on the installer contacts the housing (Fig. 8).

When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

4. Install the current roller type bearing and pin in the spring lever. Press the pin below the surface of the lever and stake it at three places on both sides of the lever. The former ball–type bearing (with two washers) is swaged at both ends to retain the bearing in the spring lever.

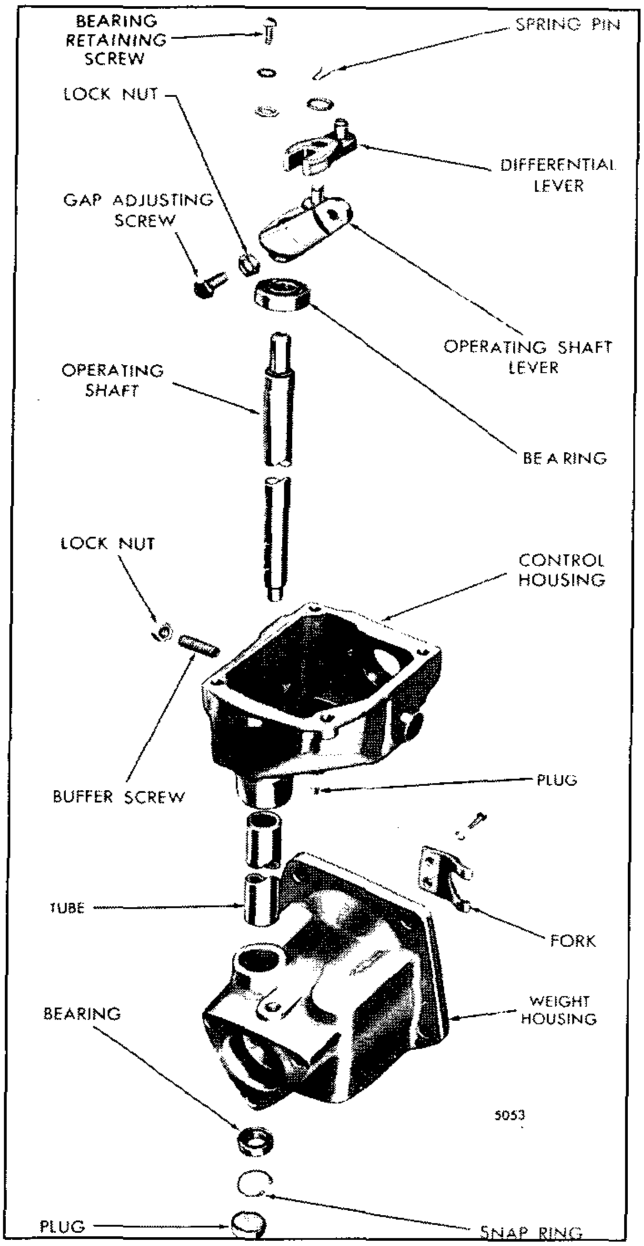


Fig. 9 – Governor Housing and Relative Location of Parts

5. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

6. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

7. Insert the correct end of the single or double lever type speed control lever shaft (Fig. 6) through the bearing bore in the side of the spring housing opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

8. Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.

9. Place the second needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

10. Remove the bearing pilot rod J 9196–2 from the installer body J 9196–1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press and press the bearing in the housing until the shoulder on the installer contacts the housing (Fig. 8).

11. If a single lever shaft was installed in the spring housing, apply a thin coat of sealing compound to the outside diameter of a new cup plug. Start the plug straight in the bearing bore in the housing, then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press and press the plug in flush with the outside face of the housing.

12. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then, tighten the spring lever retaining set screw to 5–7 lb–ft (7–10 N·m) torque.

13. Stake the edge of the set screw hole with a small center punch and hammer to retain the set screw in the lever. Then, install the plug in the spring housing on former governors.

14. On a single lever shaft, place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

15. On a double lever shaft, place a seal ring over each end of the shaft and push them into the bearing bores and against the bearings. Place a plain washer over each end of the shaft and against the housing, then install a Woodruff key in the keyway at each end of the shaft.

16. Place the speed control lever on the shaft in its *original* position. Align the keyway in the lever with the key in

the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lock washer.

Assemble Control Housing

1. If necessary, assemble the control housing to the weight housing using a good quality sealant between the tube and the housings.
2. Install the lower governor operating shaft bearing, with the number side facing out, in the weight housing (Fig. 9). Install the snap ring to secure the bearing. Lubricate the bearing with engine oil.
3. Apply a good quality sealant around the edge of a new plug and tap it in place in the weight housing.
4. Start the upper bearing, number side up, on the upper end of the governor operating shaft. Support the shaft on the bed of an arbor press. Place a sleeve against the inner race and press the bearing against the shoulder on the shaft.
5. Place the operating shaft lever on the shaft with the flat on the shaft registering with the flat in the lever. Press the lever tight against the bearing.
6. Lubricate the bearing with engine oil. Insert the lever and shaft assembly in the control housing and guide the lower end of the shaft into the bearing in the weight housing.
7. Install the upper bearing retaining screw and washers.
8. Place the fork against the operating shaft, with the two cam faces of the fork facing away from the governor weights. Thread the fork attaching screws in approximately two or three turns. The screws are to be tightened after the weight and shaft assembly is installed.
9. Place the differential lever over the pin in the governor operating shaft lever (Fig. 9). Secure the lever in place with a washer and spring pin.
10. Install the buffer screw and locknut, leaving approximately .750" of the screw extending from the governor housing.
11. If previously removed, install the gap adjusting screw and locknut in the operating shaft lever.

Assemble Weight and Shaft Assembly

1. If the weight carrier was removed from the weight shaft, press the carrier on the shaft so as to allow a clearance of .001" to .006" between the shaft shoulder and the rear face of the weight carrier.
2. Press the bearing in the retainer (press on the outer race) – (Fig. 5). Then, install the snap ring, with the flat side of the ring facing the bearing.
3. Press the bearing and retainer assembly on the shaft until the bearing contacts the shoulder on the shaft. Press on the inner race of the bearing.
4. Lubricate the shaft with clean engine oil. Then, slide the riser and bearing assembly on the shaft.
5. Secure the weights to the carrier as follows:
   a. Position one of the weights in the carrier. If the current steel carrier is used, place a spacer on each side of the weight.
   b. Insert the serrated end of the weight pin through the larger opening in the carrier and through the weight and spacers. Then, drive the pin into the smaller opening in the carrier.
   c. Install a retainer in the groove of the pin.
   d. Install the second weight in the same manner.
6. Slide the shaft and weight assembly into the weight housing, with the riser bearing positioned behind the operating fork.
7. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Then, tighten the two fork attaching screws with a 5/16" electrician's socket wrench (Fig. 6).
8. Turn the bearing retainer until the counterbored notch above the large opening in the retainer and the tapped hole in the housing are aligned. Secure the bearing retainer to the housing with a flat head screw.
9. Place the governor drive gear spacer on the shaft. Install the key and start the gear on the shaft.

   NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

   The hardened gears are used on 3–53 turbocharged industrial engines. This change became effective with engine serial number 3D–193516.
10. Tap the gear until the gear and spacer contact the inner race of the weight shaft bearing.
11. Install the gear retaining nut and tighten it to 125–135 lb–ft (170–183 N·m) torque.

Install Governor

Refer to Fig. 1 and install the governor as follows:

1. Attach the fuel rod to the differential lever and secure it in place with a washer and spring pin.
2. Attach a new gasket to the governor weight housing.

3. Insert the end of the fuel rod through the hose and clamps and into the opening in the cylinder head and position the governor weight housing against the engine rear end plate; the teeth on the governor drive gear must mesh with the teeth on the camshaft gear or balance shaft gear.

4. Install the three 12–point head bolts with copper washers in the governor weight housing next to the cylinder block. Install the two remaining bolts with steel washers and lock washers. Tighten the bolts to 35 lb–ft (47 N·m) torque.

5. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 10–12 lb–ft (14–16 N·m) torque.

6. On current engines, install the lubricating oil lines and fittings from the weight housing to the cylinder block and the control housing.

7. Align and tighten the hose clamps on the fuel rod cover.

8. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

9. Refer to Fig. 3 and attach the variable speed spring and housing to the governor as follows:

   a. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and a lock washer.

   b. If removed, start the variable speed spring plunger guide straight in the boss inside the governor housing and tap it into place with a small brass rod and hammer.

   c. Lubricate the small end of the variable speed spring plunger with engine oil. Then, insert the plunger in the plunger guide inside the governor housing.

   d. Insert the solid stop in the counterbore of the governor housing.

   e. Lubricate the outside diameter of the spring retainer with engine oil and insert it, solid end first, in the spring housing and against the spring lever.

   f. Place the same amount of shims in the spring retainer that were removed, thin shims first. Then, insert the split stop in the spring housing approximately 1/16″ from the finished face of the housing.

   Do not use shims with an 11/32″ I.D. with a spring retainer which has only one air bleed hole. Shims with a 3/4″ I.D. may be used with a spring retainer which has either one or three air bleed holes (provided only one spring is used).

   g. Insert the variable speed spring in the spring retainer with the tightly wound end of the spring against the shims.

   h. On former governors, insert two bolts (with lock washers) through the spring housing (through the spring housing cover and spring housing on current governors) and place a new gasket over the bolts and against the housing. On current governors, use copper washers with the two attaching bolts.

   i. Place the spring housing in position against the governor housing, with the spring over the end of the spring plunger inside of the governor housing.

   j. Thread the two spring housing retaining bolts into the governor housing and tighten them to 13–17 lb–ft (18–23 N·m) torque.

   k. Install the idle speed adjusting screw and locknut in the spring housing (former governors) or in the spring housing cover (current governors). Then thread the idle speed adjusting screw in approximately 1″.

10. Place a new gasket on the governor housing, then install the governor cover and lever assembly. Be sure the pin in the throttle shaft enters the slot in the differential lever. Secure the cover to the governor with four screws and lock washers. If a torsion–type stop lever spring is used, a special cover screw is used to hold the spring in place (Fig. 2). If a long coil spring is used, the spring retaining bracket is held in place by one of the standard cover retaining screws.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the overnor stop lever. *An overspeeding engine can result in* engine damage which could cause personal injury.

11. Hook the stop lever spring to the lever and to the spring retaining bracket or the special cover screw.

12. Install the fuel pump and fuel lines.

13. Perform an engine tune–up as outlined in Section 14.

VARIABLE SPEED MECHANICAL GOVERNOR (OPEN LINKAGE)

IN-LINE ENGINES

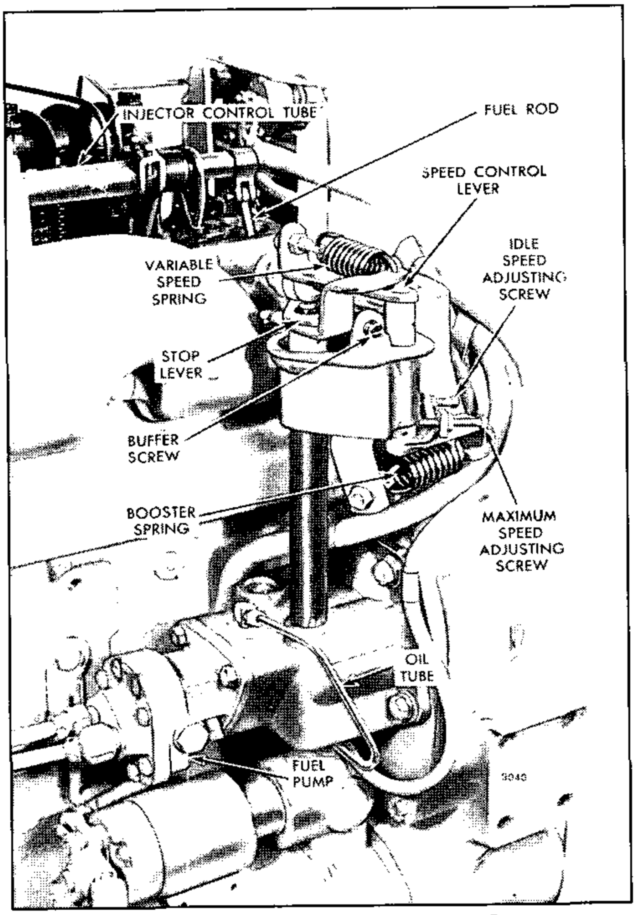


Fig. 1 – Variable Speed Open Linkage Governor Mounted on Engine

The variable speed open linkage governor (Fig. 1) performs the following functions:

1. Controls the engine idle speed.
2. Limits the maximum no–load speed.
3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single–weight governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In its normal position, the stop lever holds the fuel injector racks near the full–fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and the operating shaft to the operating shaft lever. Movement of this lever is transmitted to the stop lever which changes the fuel setting of the injector racks, since the fuel rod is connected between the stop lever and the injector control tube.

The centrifugal force of the governor weights is opposed by the variable speed spring which is fastened to the end of the operating shaft lever. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no–fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.4.2.

Lubrication

The governor is lubricated by oil splashed from the engine gear train. The oil passes through the governor weight housing to the shaft and weight assembly. The revolving weights distribute the oil to the various moving parts of the governor. The surplus oil drains back to the engine crankcase through holes in the governor bearing retainer.

The clearance between the riser tube and the weight shaft has been reduced with the use of current governor assemblies. To ensure adequate lubrication of the riser tube, an oil tube has been added between the oil gallery in the cylinder block and the top of the weight housing to supply oil under pressure.

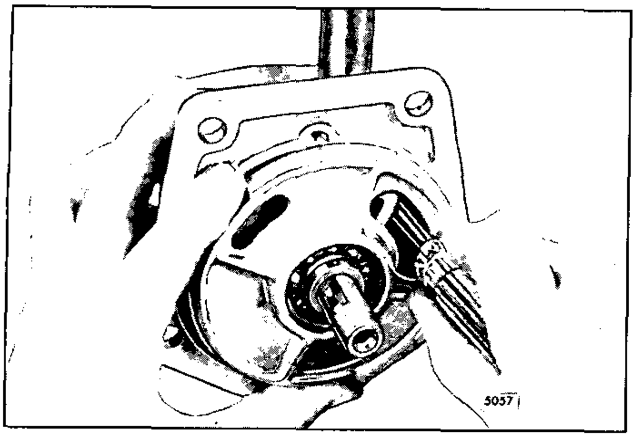


Fig. 2 – Removing or Installing Operating Shaft Fork

Remove Governor from Engine

Check the operation of the governor as outlined in Section 2.7 before removing it from the engine. If the governor fails to control the engine properly after performing these checks, it should be removed and reconditioned.

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect the fuel rod from the stop lever.
2. Disconnect the throttle control rod from the speed control lever.
3. Disconnect the fuel lines and remove the fuel pump from the governor weight housing.
4. Remove the governor lubricating oil tube, if used.
5. Withdraw the five bolts from the weight housing and the two bolts from the control housing; then, remove the governor and gasket from the engine.

Disassemble Weight Housing

1. Remove the governor drive gear retaining nut. Then remove the gear, key and spacer from the shaft.
2. Remove the small flat head screw (Fig. 3) which holds the bearing retainer in place.
3. Turn the bearing retainer until the large opening is centered over the fork on the governor operating shaft (Fig. 2).
4. Lift up on the weight shaft to provide clearance for a 5/16" electrician's socket wrench. Then remove the two retaining screws and washers and withdraw the governor operating fork.
5. Remove the shaft and weight assembly from the governor weight housing.
6. Inspect the bushing in the weight housing. If the bushing is worn or pitted, press it out of the housing and install a new bushing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer (Fig. 3) from the weight shaft.
2. If necessary, remove the snap ring and press the bearing from the retainer.
3. Remove the weight pin retainers and drive the pins out of the carrier and weights. Remove the weights. *The weight pin hole in the carrier is larger at the side where the pin retainers are located.*
4. Slide the riser and bearing assembly from the shaft. Do not attempt to remove the bearing since the riser and bearing are serviced only as an assembly.

Disassemble Control Housing

1. Remove the outer nut on the variable speed spring eye bolt. Then remove the spring and eye bolt.
2. Pry the plug from the bottom of the weight housing.
3. Remove the snap ring from the lower end of the operating shaft and tap the shaft and lever assembly out of the control housing.
4. Remove the snap ring and press the lower operating shaft bearing out of the weight housing.
5. Withdraw the outer nut and remove the booster spring and eye bolt.

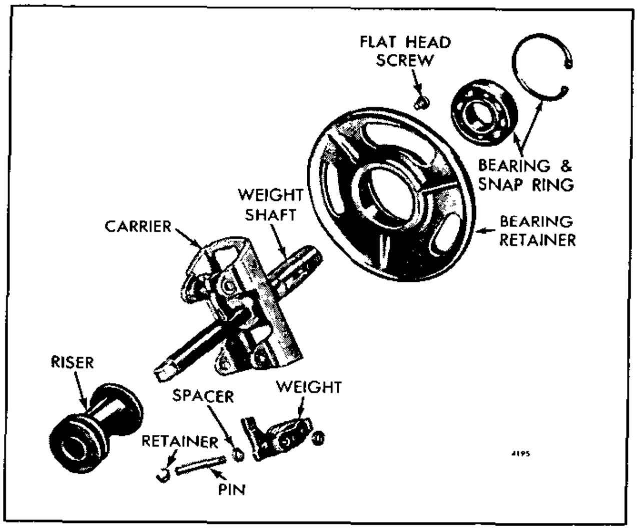


Fig. 3 – Governor Weight Details and Relative Location of Parts

6. Drive the pin from the speed control lever and remove the lever from the shaft.
7. Slide the shaft and booster spring bracket from the housing.
8. Remove the buffer screw.
9. Disengage the small spring between the operating shaft lever and the stop lever.
10. Remove the retaining ring and washer and lift the stop lever from the operating shaft.
11. Drive the pin from the operating shaft lever and remove the lever from the shaft.
12. Slide the bearing shield from the operating shaft.
13. Press the bearing from the operating shaft.

Inspection

Clean all of the parts (except the shielded upper operating shaft bearing) with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Revolve the ball bearings slowly by hand. Replace bearings which indicate rough or tight spots. Also replace bearings which are corroded or pitted.

The lower governor drive components have been revised to reduce the clearance between the riser and the weight shaft. With this change, additional lubrication is provided to the governor by an oil tube connected between the oil gallery in the cylinder block and the governor weight housing. When replacing the riser assembly, shaft and carrier assembly or the complete governor assembly, the new oil tube must be installed to provide adequate lubrication.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and bearing assembly.

Inspect the weight carrier, weights and retaining pins for wear.

Examine the fuel pump drive end of the weight shaft. Replace the shaft if the end is worn or rounded.

Inspect the bushings in the control housing. If they are worn, drive the bushings out and install new ones. Press the upper bushing in until it contacts the shoulder in the housing. Press the lower bushing to the dimension shown in Fig. 4.

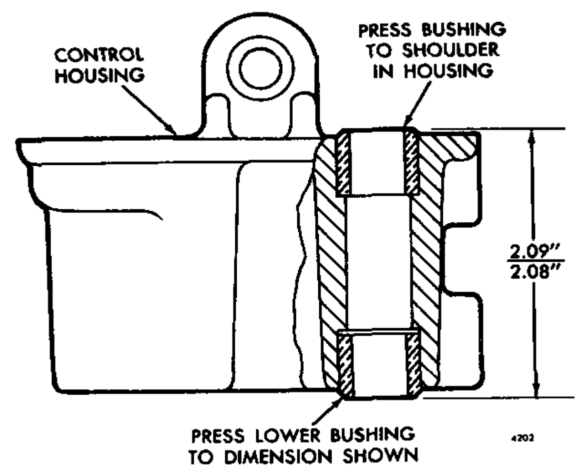


Fig. 4 – Bushings in Control Housing

Assemble Control Housing

Refer to Fig. 5 and assemble the control housing as follows:

1. Start the upper bearing, number side up, on the governor operating shaft. Support the shaft on the bed of an arbor press. Place a sleeve against the inner race and press the bearing against the shoulder on the shaft.
2. Slide the bearing shield on the shaft.
3. Place the operating shaft lever on the shaft and align the retaining pin holes. Then drive the retaining pin in place to secure the lever to the shaft.
4. Place the stop lever on the operating shaft and secure it in place with the washer and retaining ring. Then hook the small spring to the stop lever and operating shaft lever.
5. Install the lower operating shaft bearing, number side out, in the weight housing. Install the snap ring to secure the bearing. Lubricate the bearing with engine oil.
6. Insert the operating shaft and lever assembly in the control housing. Tap the shaft into the lower bearing and install a snap ring on the end of the shaft.
7. Apply a good quality sealant around the edge of the plug and tap it in place in the weight housing.
8. Place the fork against the operating shaft, with the two cam faces of the fork facing away from the governor weights. Thread the fork attaching screws in approimately two or three turns. The screws are tightened after the weight and shaft assembly is installed.

9. Install the booster spring bracket.

10. Slide the speed control shaft assembly in the control housing. Then place the speed control lever on the shaft and tap the pin in place to secure the lever.

11. Install the booster spring and the variable speed spring.

12. Install the buffer screw.

Assemble Weight and Shaft Assembly

1. If the weight carrier was removed from the weight shaft, press the carrier on the shaft so as to allow a clearance of .001" to .006" between the shaft shoulder and the rear face of the weight carrier.

2. Press the bearing (Fig. 3) in the retainer (press on the outer race). Then install the snap ring with the flat side of the ring facing the bearing.

3. Press the bearing and retainer assembly on the shaft until the bearing contacts the shoulder on the shaft. *Press on the inner race of the bearing.*

4. Lubricate the shaft with clean engine oil. Then slide the riser and bearing assembly on the shaft.

5. Secure the weights to the carrier as follows:

   a. Position one of the weights, with a spacer on each side, in the carrier.

   b. Insert the serrated end of the weight pin through the larger opening in the carrier and through the weight and spacers. Then drive the pin into the smaller opening in the carrier.

   c. *Install a retainer in the groove of the pin.*

   d. Install the second weight in the same manner.

6. Slide the shaft and weight assembly into the weight housing, with the riser bearing positioned behind the operating fork.

7. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Then tighten the two fork attaching screws with a 5/16" electrician's socket wrench.

8. Turn the bearing retainer until the counterbored notch above the large opening in the retainer and the tapped hole in the housing are aligned. Secure the bearing retainer to the housing with a flat head screw.

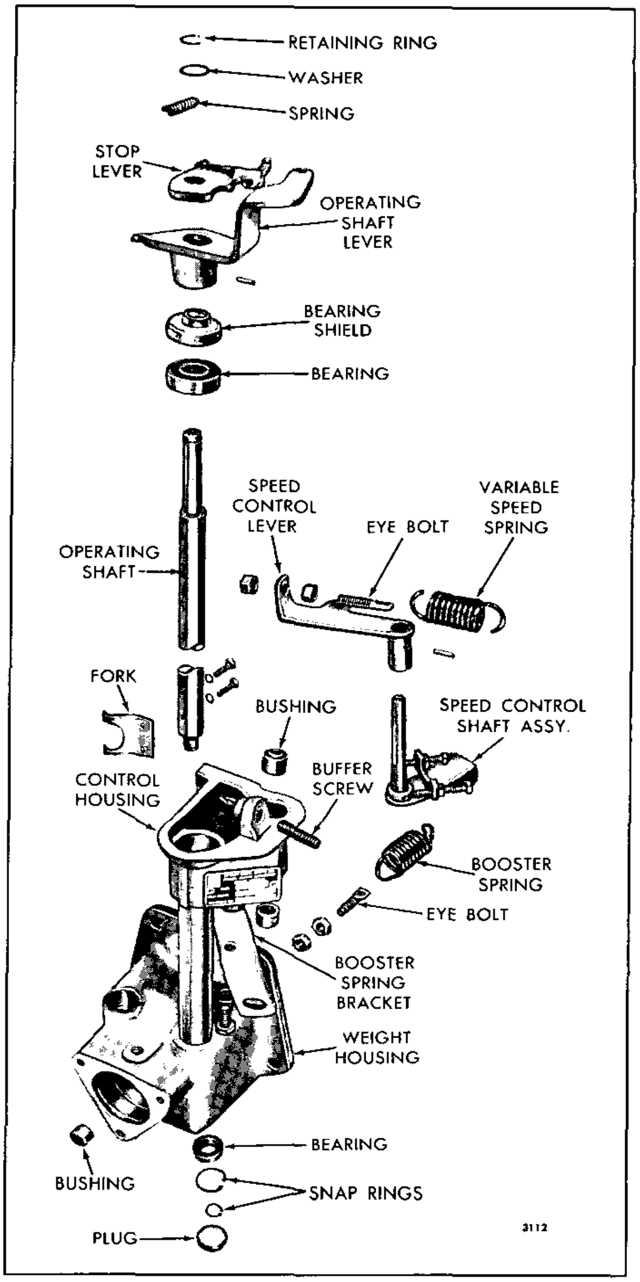


Fig. 5 – Governor Housing Details and Relative Location of Parts

9. Place the governor drive gear spacer on the shaft. Install the key and start the gear on the shaft.

10. Tap the gear until the gear and spacer contact the inner race of the weight shaft bearing.

11. Install the gear retaining nut and tighten it to 125–135 lb-ft (170–183 N·m) torque.

Install Governor

Refer to Fig. 1 and install the governor as follows:

1. Attach a new gasket to the governor weight housing.
2. Position the governor against the engine rear end plate. The teeth on the governor drive gear must mesh with the teeth on the camshaft gear or balance shaft gear.
3. Install the three 12–point head bolts with copper washers in the governor weight housing next to the cylinder block. Install the two remaining bolts with steel washers and lock washers. Tighten the bolts to 35 lb–ft (47 N·m) torque.
4. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 35 lb–ft (47 N·m) torque.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

5. Attach the fuel rod to the stud on the stop lever.
6. Install the fuel pump and fuel lines.
7. If required, install the governor lubricating oil tube and fittings.
8. Perform an engine tune–up as outlined in Section 14.4.2.

VARIABLE SPEED MECHANICAL GOVERNOR

8V ENGINE

The variable speed mechanical governor, illustrated in Fig. 1, performs three functions:

1. Controls the engine idle speed.
2. Limits the maximum no–load speed.
3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The governor is identified by a name plate attached to the governor housing. The letters S–W.–V.S. stamped on the name plate denote a single–weight variable speed governor.

As shown in Fig. 2, the governor is mounted on the front end of the blower and driven by one of the blower rotors. The governor assembly consists of three subassemblies:

1. Control housing cover.
2. Variable speed spring housing and shaft.
3. Control and weight housing.

Operation

Two manual controls are provided on the governor: a governor stop lever and a speed control lever. For starting, the governor stop lever is moved to the RUN position; this moves the injector control racks to the full–fuel position. Upon starting, the governor moves the injector racks out to the position required for idling. The engine speed is then controlled manually by movement of the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever (Fig. 1). One end of the operating shaft lever bears against the variable speed spring plunger, while the other end provides a changing fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever create an unbalanced force between the revolving governor weights and tension on the variable speed spring. When the two forces are equal, the engine speed stabilizes for a setting of the speed control lever.

Fuel rods connected to the injector control tube levers and the control link operating lever assembly are operated by the differential lever, through the operating lever connecting link. This arrangement provides a means for the governor to change the fuel settings of the injector rack control levers. The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no–fuel position and held there until the engine stops.

Adjustment of the governor is covered in the *Engine Tune–Up* section of this manual.

Lubrication

The governor is lubricated by a spray of oil from a passage in the blower end plate. The revolving governor weights distribute this oil to all parts of the governor which require lubrication. Excess oil returns to the engine crankcase through passages in the blower end plate and the cylinder block.

Remove Governor from Engine

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If, after performing these checks, the governor fails to control the engine properly, it should be removed and reconditioned.

The blower and governor must be removed together as outlined under *Remove Blower* in Section 3.4.1. Then remove the governor from the blower as outlined under *Remove Accessories from Blower* in Section 3.4.1.

Disassemble Governor

Before removing any of the parts from the governor, wash the entire unit in clean fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect it for worn or damaged parts which may be repaired or replaced without complete disassembly.

With the governor cover removed from the governor housing, refer to Fig. 1 and disassemble the cover as follows:

1. Disassemble the governor cover:
   a. Clamp the cover assembly in a vise equipped with soft jaws.

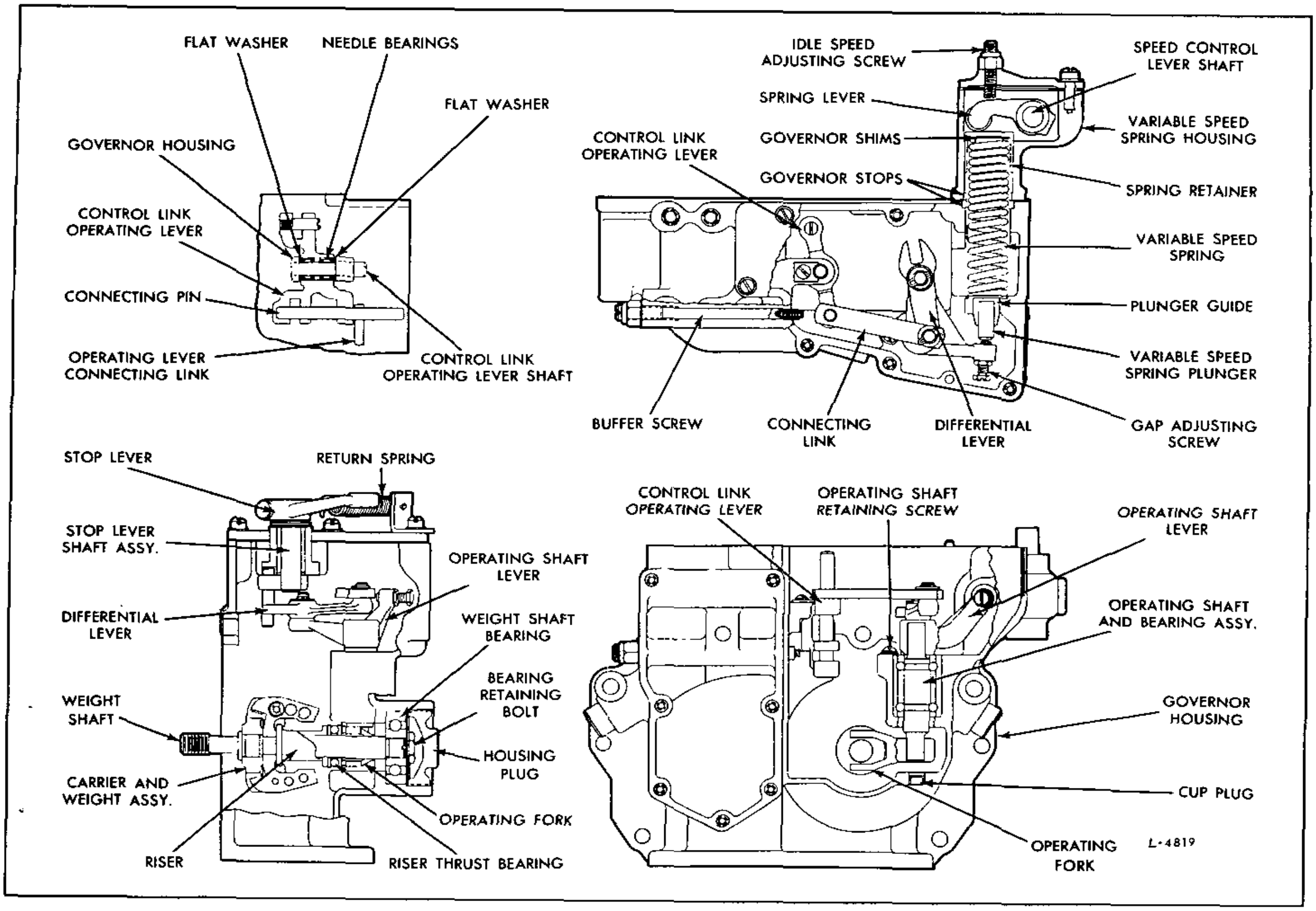


Fig. 1 – Cross Sections of Variable Speed Mechanical Governor

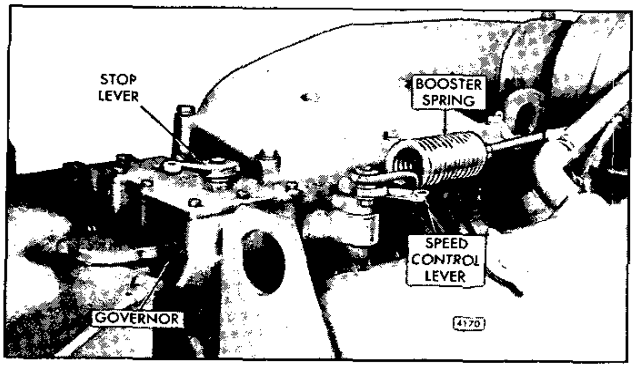


Fig. 2 – Variable Speed Governor Mounting

b. Loosen the stop lever retaining bolt and pull the lever from the shaft.

c. Remove the snap ring from the groove in the stop lever shaft and remove the two seal ring retainers.

d. Pull the stop lever shaft out of the cover and remove the seal ring (on top of the bushing) from the cover.

e. At this stage of disassembly, wash the cover assembly thoroughly in clean fuel oil and inspect the bushing for wear and damage. If the bushing is satisfactory for further use, removal is unnecessary. If worn excessively or damaged, replace the bushing.

f. If bushing removal is necessary, support the inner face of the cover over the opening in the bed of an arbor press. Place the remover J 21967–01 on top of the stop shaft bushing and press the bushing out of the cover (Fig. 3).

2. Remove the variable speed spring, spring plunger and spring housing assembly from the governor housing.

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

b. Remove the two bolts and lock washers securing the variable speed spring housing to the governor housing. Then withdraw the spring housing, spring retainer, shims, stop and spring as an assembly from the governor housing. Remove the spring housing gasket.

c. Remove the variable speed spring, split stop, shims and spring retainer from the spring housing. Then remove the spring plunger from the plunger guide.

d. Remove the spring retainer solid stop from the governor housing.

e. If necessary, remove the variable speed spring plunger guide from the governor housing with a small brass rod and hammer.

3. Disassemble the variable speed spring housing:

a. Loosen the bolt securing the speed control lever to the speed control shaft and pull the lever from the shaft.

b. Remove the Woodruff key and flat washer from the speed control shaft.

c. On the former spring housing, remove the pipe plug in the top of the spring housing. On the current spring housing, remove one screw and lock washer and remove the spring housing cover and gasket. Then remove the set screw from the spring lever (Fig. 4).

d. Place a 3/4" inside diameter sleeve approximately 1-1/2" long on the bed of an arbor press. Support the spring housing assembly on top of the sleeve with the cup plug in the side of the housing over the opening of the sleeve.

e. Place a small brass rod on the end of the shaft and under the ram of the press as shown in Fig. 5 and press the plug and bearing out of the spring housing.

f. Remove the spring lever from the spring housing and the bearing from the speed control shaft. If necessary, remove the Woodruff key from the shaft.

NOTICE: Due to the Woodruff key in the speed control shaft, the inner end of the needle bearing will be damaged when pressing the bearing and cup plug out of the spring housing. Do not reuse the bearing.

g. At this stage of disassembly, wash the spring housing (containing the remaining bearing) thoroughly in clean fuel oil and inspect the needle bearing for wear and damage. If the bearing is satisfactory for further use, removal is unnecessary.

h. If removal of the needle bearing is necessary, support the spring housing, bearing side down, on top of the 3/4" inside diameter sleeve on the bed of the arbor press. Insert the bearing remover J 21967-01 through the housing and rest it on top of the bearing, then press the bearing out of the housing.

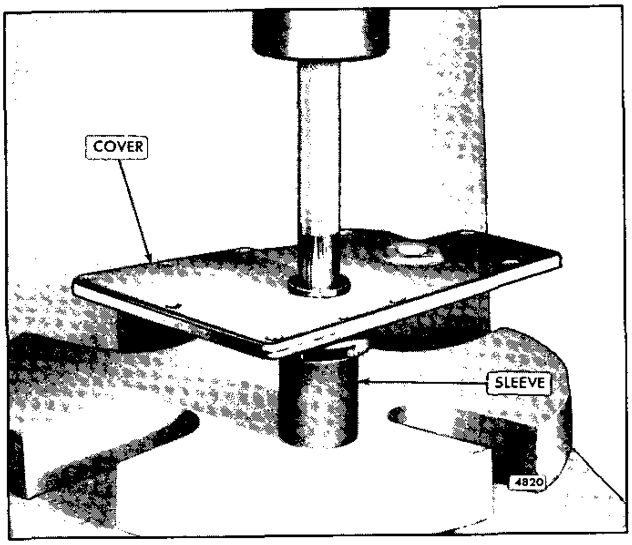


Fig. 3 - Removing Stop Lever Shaft Bushing from Governor Cover Using Tool J 21967-01

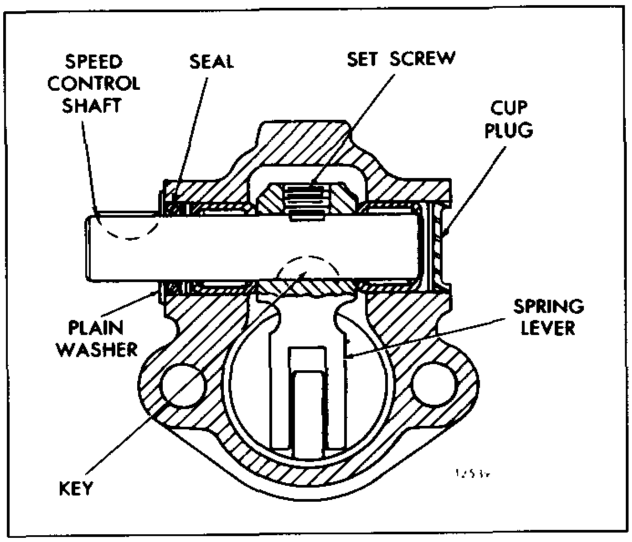


Fig. 4 - Cross Section of Governor Spring Housing and Lever Assembly

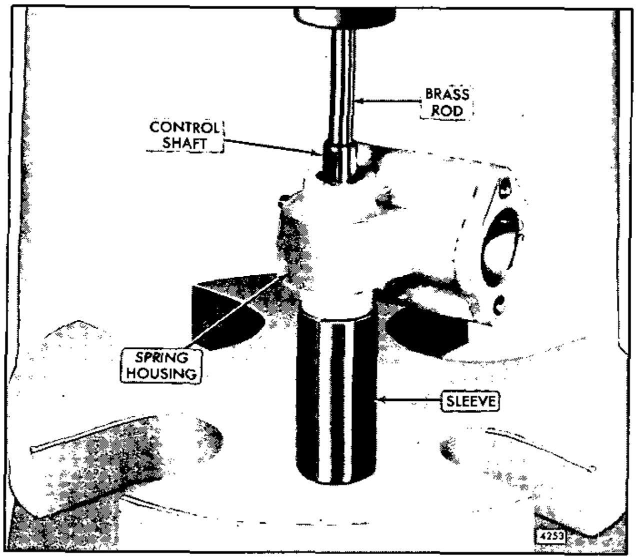


Fig. 5 – Removing Speed Control Shaft, Bearing and Cup Plug from Governor Spring Housing

4. Remove the governor weight and shaft assembly from the governor housing as follows:

   a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

   b. Remove the governor weight housing plug and gasket (Fig. 1).

   c. Bend the tang on the lock washer away from the head of the bolt. Then, while holding the weight carrier from turning, remove the bearing retaining bolt, flat washer and lock washer.

   d. Place a 1/4" brass rod in the bearing retainer bolt hole in the weight carrier shaft, then tap the shaft out of the weight shaft bearing with a hammer. Catch the shaft and weight carrier assembly by hand to prevent it from falling and being damaged.

   e. Slide the governor riser thrust bearing and riser from the weight shaft.

   The thrust bearing is specially designed to absorb thrust load; therefore, looseness between the mating parts does not indicate excessive wear.

   f. Remove the weight shaft bearing from the governor housing. If necessary, use a small brass rod and hammer and tap the bearing out of the housing.

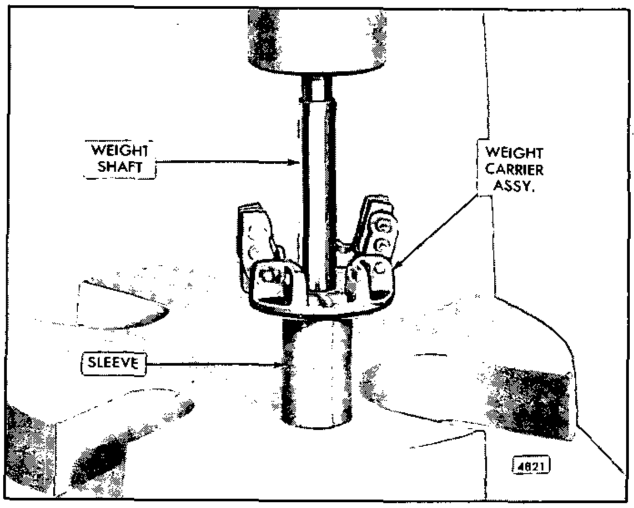


Fig. 6 – Removing Governor Weight Shaft from Weight Carrier Assembly

5. Disassemble the governor weights and shaft assembly as follows:

   a. If removal of the weight carrier assembly from the shaft is necessary, support the shaft, weight carrier and sleeve on the bed of an arbor press as shown in Fig. 6 and press the shaft out of the weight carrier assembly.

   b. Remove the weight pin retainer from each weight pin (Fig. 12). Clamp the weight carrier assembly in a vise equipped with soft jaws, then drive the pin out of the carrier and weights by tapping on the grooved end of the pins with a small punch and hammer. Remove the weights from the carrier.

6. Remove the governor linkage and operating shaft from the governor housing as follows:

   a. Remove the spring retainer and plain washer securing the connecting link to the differential lever and remove the connecting link.

   b. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever and remove the differential lever.

   c. Remove the screw, lock washer and lock clip securing the control link operating lever shaft in the housing. Lift the shaft out of the housing and remove the operating lever and two flat washers at each side of the operating lever. *Do not lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.*

d. Remove the cup plug in the bottom of the governor housing by tapping it out of the housing, toward the operating fork, with a 1/4" rod and hammer.

e. Remove the operating shaft and bearing assembly retaining screw, lock washer and flat washer securing the shaft and bearing assembly in the governor housing.

f. Support the governor housing, bottom side up, on two wood blocks on the bed of an arbor press as shown in Fig. 7. Place a 9/16" open end wrench under the operating fork and the boss of the housing, then insert a rod through the cup plug hole in the housing and against the end of the operating shaft and press the shaft and bearing assembly out of the operating fork.

g. Remove the governor operating shaft lever, shaft and bearing assembly from the governor housing.

h. Examine the operating shaft bearing for wear and rough spots and, if replacement is necessary, remove the operating shaft lever from the shaft with a small puller.

i. Remove the buffer screw from the governor housing and, if desired, remove the lock nut from the screw.

j. Remove the bolts, lock washers and plain washers securing the breather hole cover to the governor housing, then remove the cover and gasket.

k. Wash the control link operating lever (containing the bearings) thoroughly in clean fuel oil and inspect the needle bearings for wear or damage. If the needle bearings are satisfactory for further use, removal is unnecessary.

l. If removal of the needle bearing is necessary, support the control link operating lever on a sleeve and rest the sleeve on the bed of an arbor press. Place tool J 8985 on top of the bearing and under the ram of the press, then press both bearings out of the lever as shown in Fig. 8.

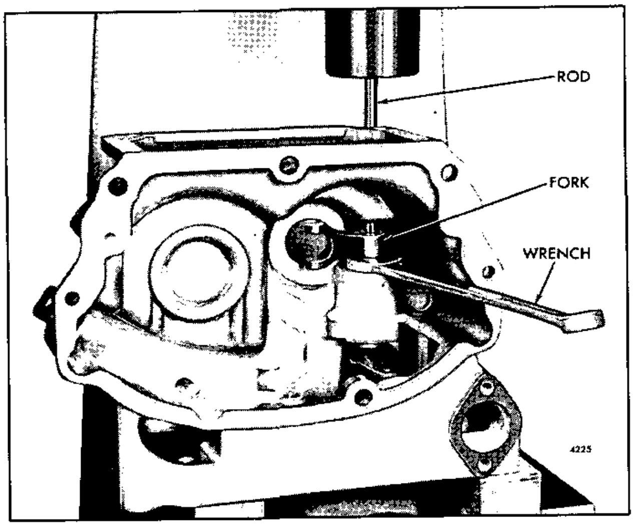


Fig. 7 – Removing Governor Operating Fork from Operating Shaft and Bearing Assembly

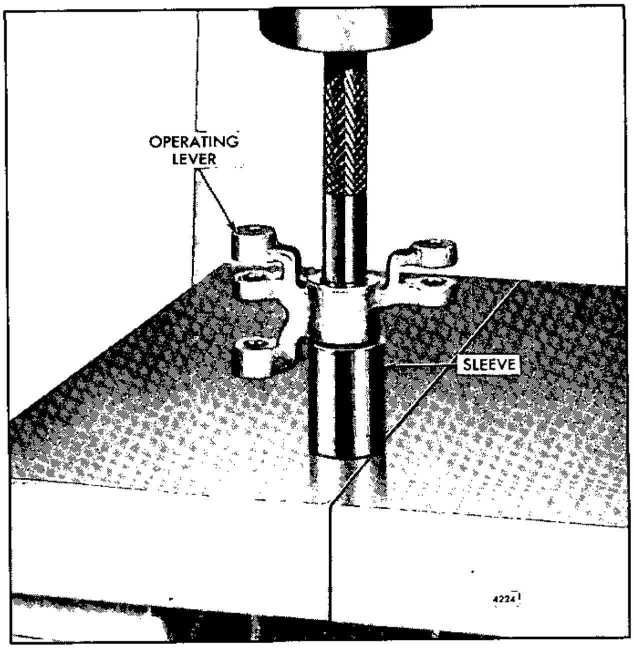


Fig. 8 – Removing Control Link Operating Lever Bearings Using Tool J 8985

Inspection

Wash all of the governor parts (except the operating shaft bearing) in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

NOTICE: The operating shaft bearing is sealed and must not be cleaned with fuel oil or other cleaning agent.

Examine the governor weight shaft bearing for any indications of corrosion or pitting. Lubricate the bearing with light engine oil; then, while holding the bearing inner race from turning, revolve the outer race by hand and check for rough spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Examine the stop lever shaft and bushing in the governor cover for wear. The stop lever shaft bushing is not serviced. When replacement of the bushing becomes necessary, it must be replaced with two needle bearings.

Examine the weight carrier pins and pin holes in the weights for wear.

Examine the speed control shaft and needle bearing in the spring housing for excessive wear.

Inspect the variable speed spring roller bearing and pin for wear.

Inspect the serration on the end of the governor weight shaft and in the blower rotor shaft for wear.

Examine the variable speed spring lever roller and pin for excessive wear. The current roller type bearing rides on a hardened bearing pin which is a press fit in the spring lever and is staked at three places on both sides. The former ball type bearing (with two washers) rides on a soft bearing pin that is swagged at both ends to retain the bearing in the spring lever.

Examine the variable speed spring plunger, guide and spring retainer for wear or score marks. If the retainer or plunger are scored slightly, clean them up with crocus cloth. Replace the retainer, plunger and guide if scored excessively.

Inspect the adjusting screw, lock nut, pins, seal rings and any other parts in the governor housing for wear or defects that might affect the governor operation.

Replace all of the governor parts that are excessively worn or damaged.

Assemble Governor

With all of the governor parts cleaned and inspected and the necessary new parts on hand, the governor may be assembled.

Refer to Figs. 1, 9, 12, 14 and 16 for the location of the various parts and assemble the governor as follows:

1. Install the operating shaft and governor linkage in the governor housing as follows:

   a. If removed, lubricate the inside diameter of the operating shaft lever with engine oil, then start the lever on the upper end (short protruding end) of the shaft with the flat surface in the lever in alignment with the flat surface of the shaft. Support the lever, shaft and bearing assembly on the bed of an arbor press and press the lever flush with the top end of the shaft.

   b. Lubricate the outside diameter of the shaft bearing with engine oil, then insert the shaft, bearing and lever assembly in the bearing bore in the governor housing.

   c. Lubricate the inside diameter of the governor operating fork with engine oil, then start the fork on the lower end of the shaft with the flat surface in the fork in alignment with the flat surface on the shaft, and the finished cam surface of the fork facing toward the rear face of the governor housing.

   d. Insert the threaded end of the governor fork installing pin J 21995–1 through the cup plug hole in the bottom of the housing, then thread the knurled disc J 21995–2 on the end of the rod.

   e. Support the housing, lever, shaft, fork and installer, right side up, on the bed of an arbor press as shown in Fig. 10, with the end of the installer pin resting on the bed of the press and the disc centered under the bottom of the operating fork. Then place a short rod on the top end of the operating shaft and press the shaft into the fork until the fork is flush with the end of the shaft. Remove the fork installer disc and rod from the housing.

   f. Install the operating shaft and bearing assembly retaining flat washer, lock washer and screw in the governor housing and tighten the screw securely.

   g. Apply a good sealant to the outside diameter of a new cup plug. Start the cup plug, solid end first, straight in the plug hole in the bottom of the housing, then support the governor housing on the bed of an arbor press and press the plug in flush with the bottom face of the housing (Fig. 1).

   h. Place the differential lever over the pivot pin in the operating lever, pin in lever up, and secure it in place with a plain washer and spring retainer.

   i. If previously removed, install the governor gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

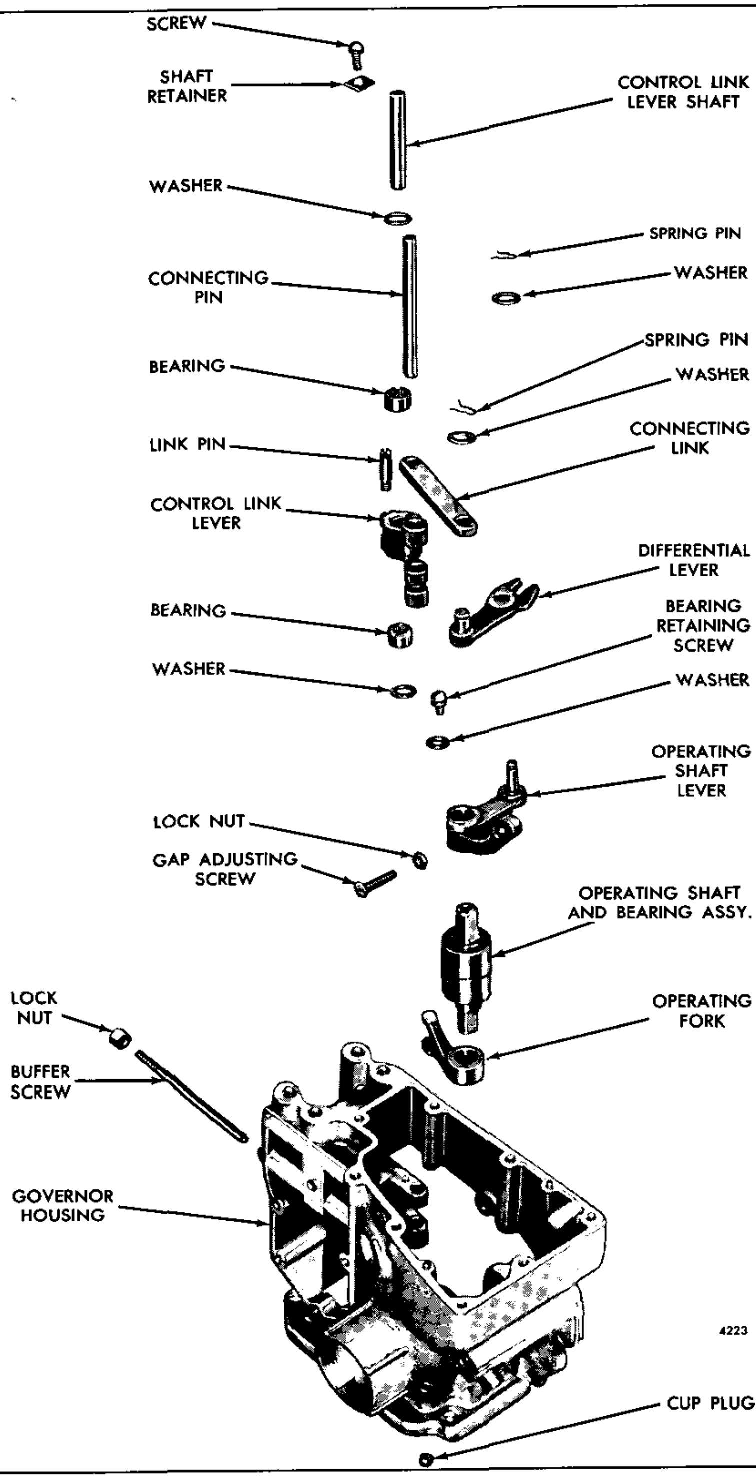


Fig. 9 – Governor Housing and Operating Shaft Details and Relative Location of Parts

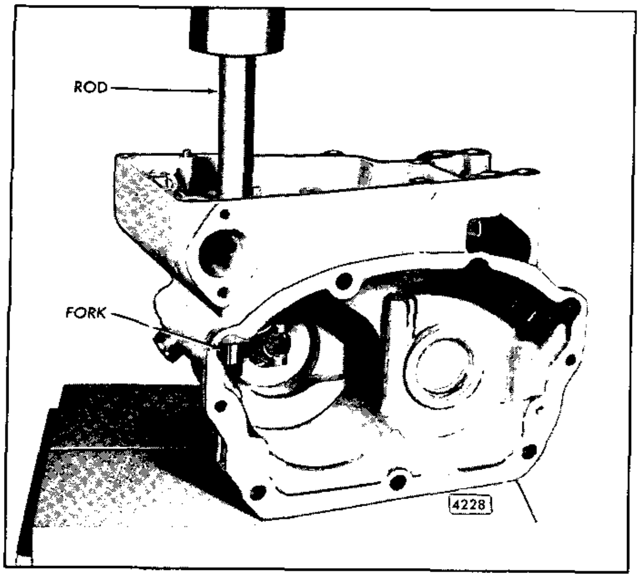


Fig. 10 – Installing Governor Operating Shaft Fork Operating Shaft and Bearing Assembly Using Tools J 21995-1 and J 21995-2

j. If removed, place the control link operating lever on the bed of an arbor press with a steel support under the bearing bore. Lubricate the bearing with engine oil and start the bearing, numbered end up, straight into the bore of the lever. Insert the pilot end of installer J 21068 in the bearing and press the bearing into the lever until it is flush with the top surface of the lever (Fig. 11). Reverse the lever on the press and install the second bearing in the same manner.

k. Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent. Place the operating lever in position between the two bosses inside the governor housing. Insert a flat washer on each side of the lever (Fig. 1). Then install the operating lever shaft with the slot in the side at one end of the shaft up.

l. Align the slot in the operating lever shaft with the lock clip screw hole in the boss next to the shaft. Install the lock clip, lock washer and screw and tighten it securely.

m. Place one end of the connecting link over the differential lever pin and secure it in place with a plain washer and spring retainer (Fig. 1). Place the opposite end of the connecting link on top of the control link operating lever and install the connecting pin.

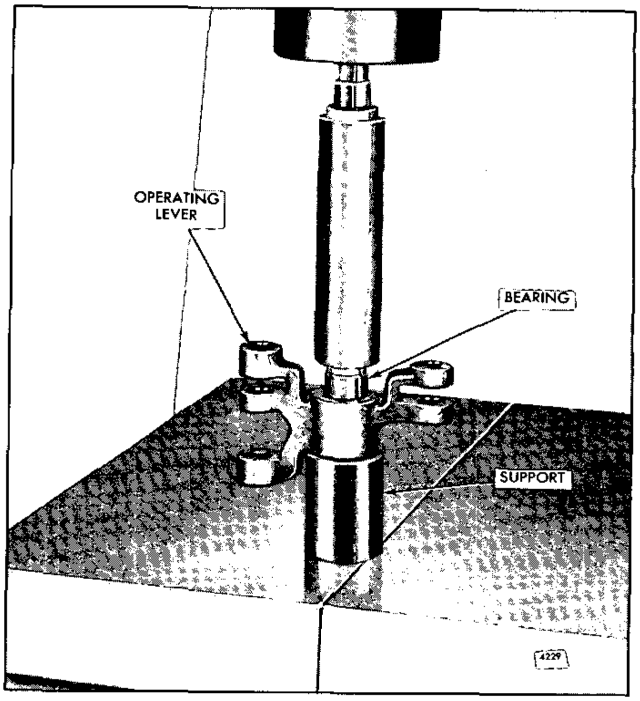


Fig. 11 – Installing Control Link Operating Lever Bearings in Lever Using Tool J 21068

n. If removed, thread the lock nut on the buffer screw and thread the buffer screw into the governor housing.

o. Affix a new gasket to the breather hole cover, then attach the cover to the governor housing with bolts, lock washers and plain washers.

2. Assemble the governor weight and shaft assembly as follows:

If the governor weight carrier assembly was removed from the weight shaft, the weights must be removed from the carrier before attempting to install the carrier on the shaft.

a. Support the weight carrier, rear face up, on a sleeve on the bed of an arbor press as shown in Fig. 13.

b. Lubricate the weight carrier surface of the weight shaft with engine oil. Insert the non–splined end of the shaft through the carrier and into the sleeve, then press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

c. Clamp the weight carrier and shaft assembly in a vise equipped with soft jaws.

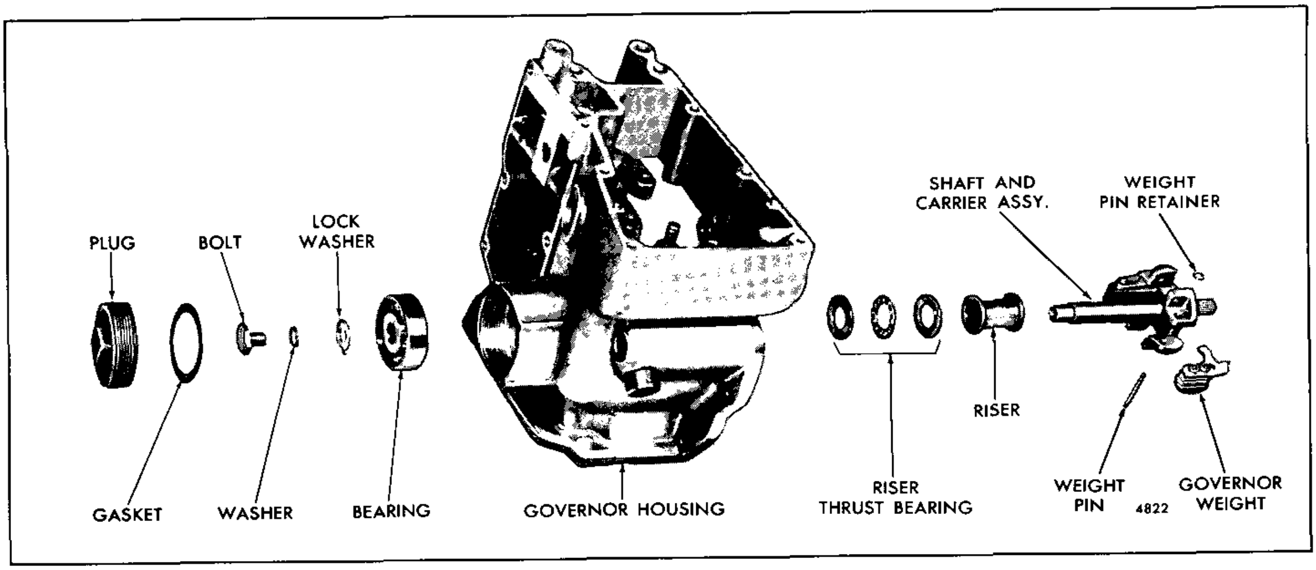


Fig. 12 – Governor Housing and Weight Details and Relative Location of Parts

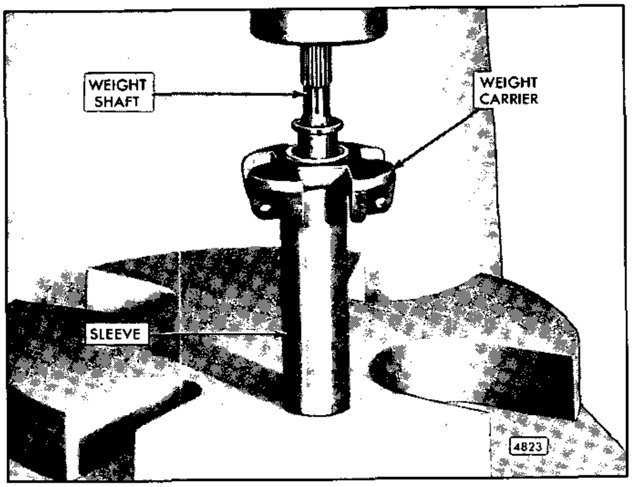


Fig. 13 – Installing Governor Weight Shaft in Weight Carrier

d. Place a governor weight in position in the carrier, then insert a weight pin, grooved end first, into the smallest pin hole in the carrier, through the weight and into the opposite hole in the carrier, then tap the knurled end of the pin into the carrier just enough to permit the pin retaining ring to be installed in the pin groove. Install the retaining ring.

e. Install the remaining governor weight in the weight carrier in the same manner as described in Step "d".

3. Install the governor weight and shaft assembly in the governor housing as follows:

a. Lubricate the weight shaft with engine oil, then slide the governor riser over the end of the shaft and against the fingers of the weight.

b. Lubricate the governor riser thrust bearing with engine oil, then place the thrust bearing over the end of the weight shaft with the bearing race which has the smallest inside diameter against the riser.

c. Insert the weight carrier and shaft assembly in the governor housing. Then support the splined end of the shaft and the governor housing on the bed of an arbor press with the upper end of the shaft under the ram of the press.

d. Lubricate the weight shaft bearing with engine oil, then place the bearing in the governor housing (numbered side up) and start it straight on the end of the weight carrier shaft. Place a sleeve with a 1/2" inside diameter on top of the bearing inner race and press the bearing into the housing and against the shoulder on the shaft.

e. Place the special lock washer on the end of the weight carrier shaft with the tang on the inner diameter of the washer in the notch in the end of the shaft.

f. Place the flat washer on the bearing retainer bolt and thread the bolt into the shaft. Clamp the splined end of the weight carrier shaft in the soft jaws of a bench vise and tighten the bearing retainer bolt to 15–19 lb-ft (20–26 N·m) torque. Bend the tang on the lock washer against the head of the bolt.

g. Place a gasket against the weight shaft bearing. Apply a good quality sealant such as Loctite

grade H, HV or HVW, or equivalent, on the threads of the governor housing and the plug and thread the plug into the housing. Clean the plug with solvent to remove any oil or grease before applying the sealant. Tighten the plug to 45 lb–ft (61 N·m) torque.

NOTICE: Rotate the governor weight assembly to see that there is no bind. If a bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

4. Refer to Figs. 4 and 14 for the location of the parts and assemble the variable speed spring housing as follows:

   a. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right–hand side of the spring housing as viewed in Fig. 4.

   b. Install the needle bearing pilot rod J 9196–2 in the installer body J 9196–1 and secure it in place with the retaining screw.

NOTICE: To avoid bearing damage, do not use impact tools to install needle bearings.

   c. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing. When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

   d. Install the current roller type bearing and pin in the spring lever. Press the pin below the surface of the lever and stake at three places on both sides of the lever. The former ball type bearing (with two washers) is swagged at both ends to retain the bearing in the spring lever.

   e. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

   f. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

   g. Insert the correct end of the speed control lever shaft (Fig. 4) through the bearing bore in the side of the spring housing, opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

   h. Thread the set screw into the spring lever, making sure the point of the screw is seated on the flat on the shaft.

   i. Place the second speed control lever shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

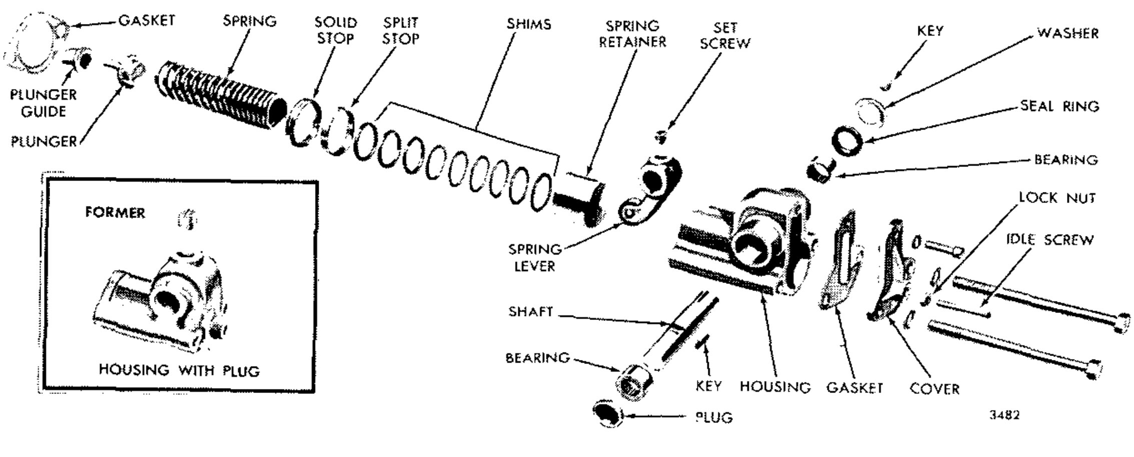


Fig. 14 – Variable Speed Spring Housing and Shaft Details and Relative Location of Parts

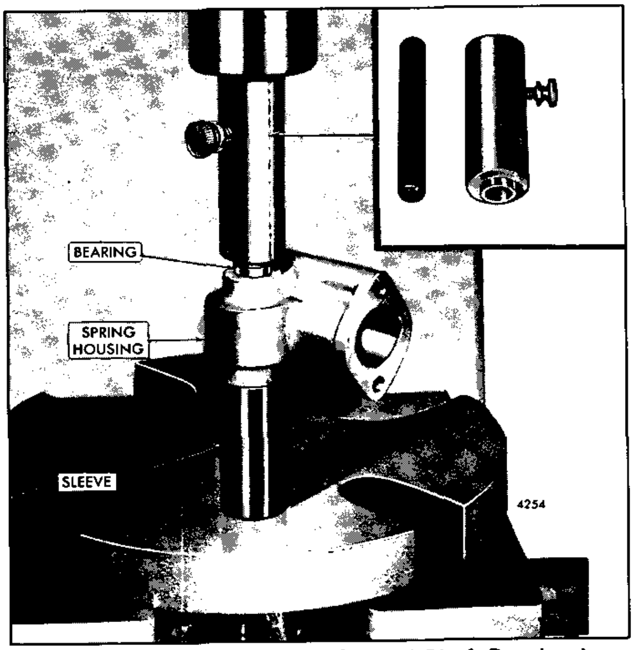


Fig. 15 – Installing Speed Control Shaft Bearing in Spring Housing Using Tool J 9196

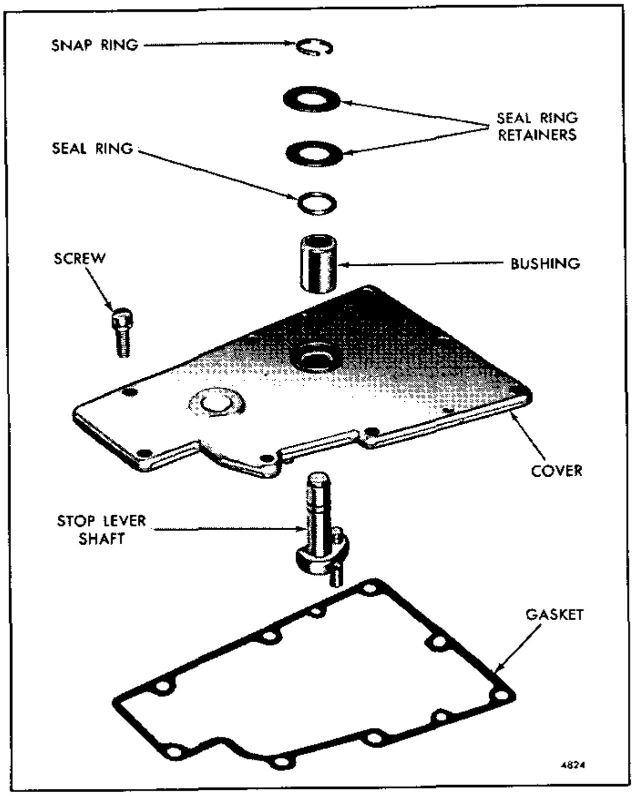


Fig. 16 – Governor Cover Details and Relative Location of Parts

j. Remove the bearing pilot rod J 9196–2 from the installer body J 9196–1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing.

k. Apply a thin coat of sealing compound to the outside diameter of the cup plug. Start the cup plug, solid end first, straight in the bearing bore in the housing. Then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press and press the cup plug in flush with the outside face of the housing.

l. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 5–7 lb–ft (7–10 N·m) torque.

m. Stake the edge of the spring lever set screw hole with a small center punch and hammer to retain the set screw in the lever. Then install the plug in the former spring housing.

n. Place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

o. Place the speed control lever on the shaft in its original position. Align the keyway in the lever with the key in the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lock washer.

p. If removed, thread the lock nut on the idle speed adjusting screw. Then thread the idle speed adjusting screw into the spring housing or spring housing cover approximately 1″.

5. Refer to Figs. 1 and and 14 and attach the variable speed spring plunger guide, plunger retainer, shims, spring, stops and spring housing assembly to the governor housing as follows:

   a. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and lock washer.

   b. Clamp the flange of the governor housing in a vise equipped with soft jaws.

   c. If removed, start the variable speed spring plunger guide straight in the boss inside the governor housing and tap it into place with a small brass rod and hammer.

   d. Lubricate the small end of the variable speed spring plunger with engine oil. Then insert the

plunger in the plunger guide inside the governor housing (Fig. 1).

e. Place the spring retainer solid stop in the counterbore of the governor housing.

f. Lubricate the outside diameter of the variable speed spring retainer with engine oil. Insert the spring retainer, solid end first, into the spring housing and against the spring lever.

g. Place the same amount of shims in the spring retainer that were removed, thin shims first. Then insert the spring retainer split stop in the spring housing approximately 1/16" from the finished face of the housing.

h. Affix a new gasket to the forward face of the spring housing. Then insert the variable speed spring into the spring housing and spring retainer with the tightly wound end of the spring against the shims in the retainer.

i. Place the variable speed spring housing into position against the governor housing, with the speed control lever facing the top of the governor (Fig. 2) and the variable speed spring over the end of the spring plunger (Fig. 1) inside the governor housing.

j. On former governors, insert two bolts with lock washers through the spring housing. On current governors, insert two bolts with copper washers through the spring housing cover and spring housing. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.

6. Refer to Fig. 16 for the location of the various parts and assemble the governor cover as follows:

a. If the stop lever shaft bushing (Fig. 16) was *removed from the cover it must be replaced with* two (2) needle bearings. Place the cover, inner face down, on the bed of an arbor press as shown in Fig. 17. Then lubricate the new needle bearing with engine oil and start the bearing, numbered end up, straight in the bearing bore in the cover boss.

b. Place the correct end of the installer J 21068 in the bearing and under the ram of the press. Then *press the bearing into the cover until the stop on* the installer contacts the boss on the cover.

c. Reverse the cover, inner face up, on the bed of an arbor press. Lubricate the second bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

d. Place the bearing installer J 21068 in the bearing and press the bearing in the bore until it is flush with the face of the boss.

e. Lubricate the stop lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then insert the stop shaft through the bearings in the cover.

f. Place the seal ring over the shaft and push it into the bearing bore and against the bearing. Place the two seal ring retainer washers on the shaft and against the cover boss, then install the snap ring in the groove in the shaft.

g. Install the stop lever on the shaft and secure it in place with the retaining bolt and lock washer.

Install Governor on Engine

1. Refer to Section 3.4.1 and attach the governor to the blower as outlined under *Attach Accessories to Blower*.

2. Install the blower and governor assembly as outlined under *Install Blower* in Section 3.4.1.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

3. Perform an engine tune-up as outlined in Section 14.

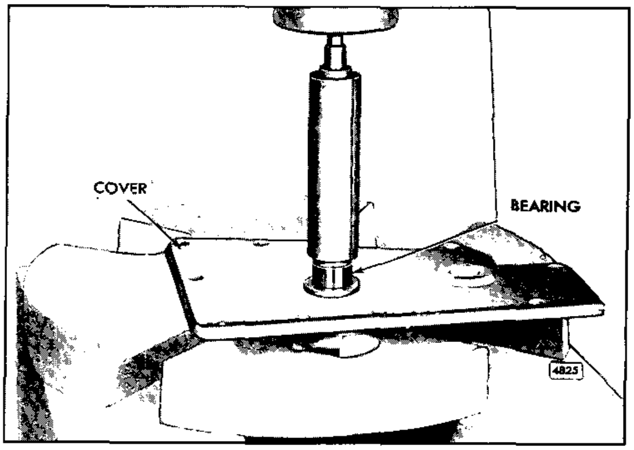


Fig. 17 – Installing Bearings in Governor Cover Using Tool J 21068

CONSTANT SPEED MECHANICAL GOVERNOR

In–Line Engine

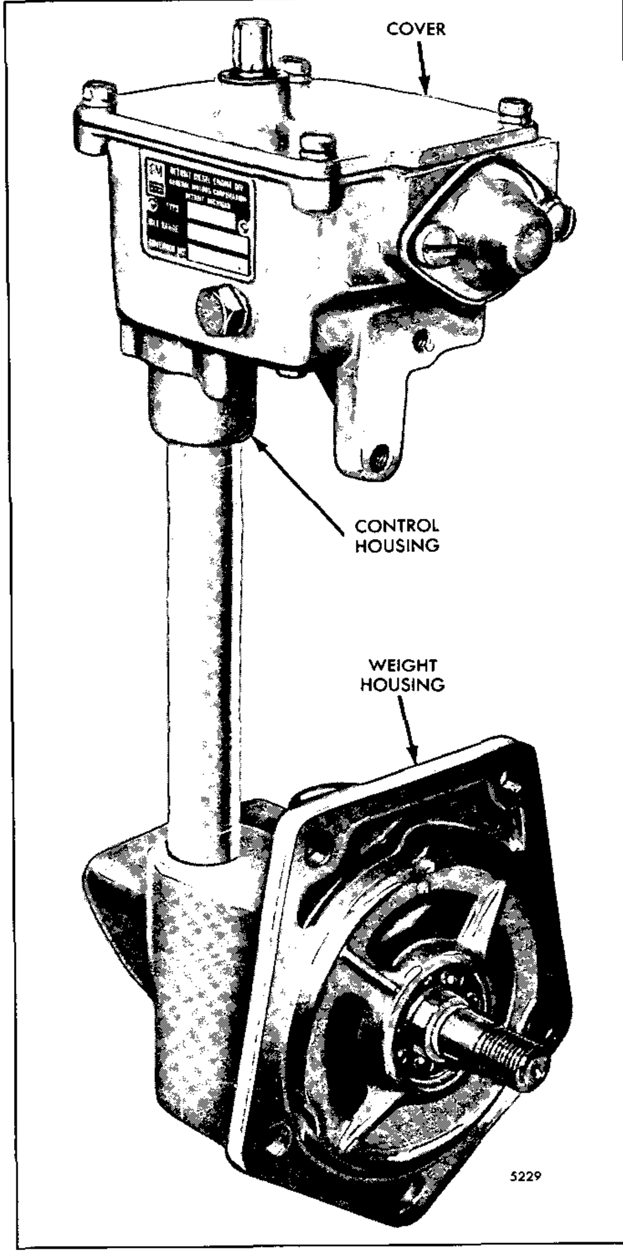


Fig. 1 – Constant Speed Governor

The horsepower requirements of an engine vary continually due to fluctuating loads; therefore, some means must be provided to control the amount of fuel required to hold the engine speed reasonably constant during such fluctuations. To accomplish this control, a mechanical governor of the constant speed type has been provided.

Upon starting, the engine will automatically attain approximately 50 rpm more than the predetermined speed.

As the load is applied the engine speed drops until it reaches the desired speed at full load. This speed can be adjusted by the use of shims behind the governor spring.

The governor is mounted on the rear end plate of the engine. The governor is driven by a gear that extends through the end plate and meshes with either the camshaft or the balance shaft gear, depending upon the engine model.

Operation

A spring on top of the governor holds the governor control lever in the *run* position. A cable from the instrument panel, when pulled, overcomes the spring and draws the injector racks to the no–fuel position (through the governor), thus stopping the engine.

The centrifugal force of the revolving flyweights is converted into linear motion which is transmitted through the riser, operating shaft, the operating shaft lever, the low speed gap screw and the plunger to the spring. The other arm of the operating lever provides a changing fulcrum on which the differential lever pivots. A fuel rod, connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The centrifugal force of the governor weights is opposed by the governor spring. Load changes create an unbalanced force between the revolving governor weights and the tension of the spring. When the two forces are equal, the engine speed stabilizes. Whenever the centrifugal force of the revolving weights overcomes the tension of the spring, the injector racks will be moved toward the no fuel position. Also, whenever the centrifugal force of the weights allows the spring to expand, the injector racks will move toward the full–fuel position.

Adjustment for the no–load speed on a single range governor is made by varying the tension of the spring by the use of shims. The addition of shims behind the spring will raise the engine speed; likewise, the removal of shims will lower the engine speed. On a dual range governor, the top speed is adjusted by the use of shims, the lower speed by use of an adjusting screw.

When governor difficulties are encountered which would necessitate governor service, refer to Section 2.7.1 for the proper procedure.

When engine tune–up is necessary, refer to Section 14.6.

HYDRAULIC GOVERNORS

Horsepower requirements on an engine may vary due to fluctuating loads. Therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage betweeen the throttle control and the fuel injectors.

Engines, subjected to varying load conditions that require an automatic fuel compensation to maintain more nearly constant engine speed with a minimum speed droop, are equipped with a hydraulic governor.

In the hydraulic governor, the fuel is decreased by the action of the governor throttle control terminal lever retracting spring and increased by the opposing action of the power piston. A pilot valve controls the admission of oil flow to the power piston and the movement of the pilot valve in turn is controlled by the governor flyweights. The centrifugal force of these flyweights is opposed by the speeder spring compression which may be varied and yet accurately set and held at any speed between idle and maximum speed. The speed droop, which is the difference between no–load speed and full–load speed, is adjustable to within a very small percentage at maximum speed.

Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine. However, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations appear, check the unit as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.

2. Check the engine to be sure that all of the cylinders are firing properly (refer to Section 15.2). If any cylinder is not firing properly, remove and test the injector and, if necessary, replace or recondition it.

3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

   With the fuel rods connected to the injector control tube levers, the mechanism must be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, locate and correct it as follows:

   a. If an injector rack sticks or moves too hard, check the injector hold–down clamp. If it is too tight or improperly positioned, loosen the clamp bolt, reposition the clamp and re–tighten the bolt to 20–25 lb–ft (27–34 N·m) torque.

   b. An internal dirt accumulation, a defective plunger and bushing or a bent injector control rack can result in bind. To correct this condition, remove the injector, then recondition and test it.

   c. An improperly positioned control rack lever will result in a binding injector rack. To relieve the bind, loosen the control rack lever adjusting screws. Then relocate the lever on the control tube and position it as outlined in Section 14.

   d. If the injector control tube binds in its support brackets, it will prevent free movement of the injector control racks to their no–fuel position. Loosen and re–align the control tube supporting brackets, then tighten the bolts to correct this condition. Reposition the injector racks after re–aligning the support brackets.

   e. Replace an injector control tube return spring which has been bent or otherwise distorted. When the injector control tube and the injector racks are free from bind, the control tube will return to the no–fuel position by action of the return spring.

NOTICE: To avoid possible engine damage, never stretch or tamper with an injector control tube return spring to change its tension. Use a new spring.

   f. Check for bind in the pins which connect the fuel rods to the injector control tube levers. If necessary, remove the pins and polish them with fine emery cloth.

4. If neither load, engine irregularities or bind are found to be the cause of the speed variations, the trouble is probably in the governor or governor drive. Check as follows:

   a. If the speed changes noted are in rapid oscillation (governor hunting), adjust the speed droop of the governor as outlined in Section 14. This applies only if the governor is overhauled or where the speed droop has been changed from the original factory setting.

   b. Worn blower rotor bearings or rubbing of the rotors on the housing will cause the load on the blower drive coupling (between the gear train and the blower) to vary erratically. This variation in load will be transmitted as a speed change to the governor. The governor will act to compensate for the change by moving the fuel rods. If this condition exists, inspect the blower.

c. If the speed variations are small in magnitude, check the governor drive. Excessive or insufficient clearance between the bevel drive gears can cause this condition.

d. If the speed variations are large and erratic and unaffected (except, perhaps, in magnitude) by changes in the speed droop adjustment, or if the governor fails to control the speed at all, replace or overhaul the governor.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor. To be certain whether the governor or engine is at fault, install a new governor (with the same part number) and check the performance of the engine.

SG HYDRAULIC GOVERNOR

The governor shown in Fig. 1 incorporates a speed droop stabilizer mechanism. Engine lubricating oil is admitted, under pressure, to an auxiliary oil pump in the governor. The auxiliary pump furnishes the necessary oil pressure to actuate the governor mechanism.

The governor is connected to the fuel injectors by a fuel rod that is attached to a lever on the injector control tube. The amount of fuel to the injectors is decreased by the governor throttle control terminal lever retracting spring and increased by the opposing action of a hydraulic power piston inside of a cylinder. Admission of oil to the cylinder is controlled by a pilot valve. The pilot valve, in turn, is controlled by the flyweights of the governor.

The two flyweights of the governor are mounted on a vertical shaft and driven, through a set of gears, by the camshaft or balance shaft gear (depending upon the engine model). The centrifugal force of the rotating flyweights is opposed by a speeder spring located on the vertical shaft between a spring fork at the top and the arms of the flyweights at the bottom. Compression of the speeder spring, which is controlled by the throttle, determines the speed at which the governor will control the engine.

In order that the governor operation may be stable (that is, without hunting), an adjustable speed droop mechanism is used in the governing system. Speed droop adjustment is achieved through a slotted bracket attached to the terminal lever. Moving the droop adjusting bracket IN toward the engine increases governor droop, and OUT, away from the engine, decreases the governor droop.

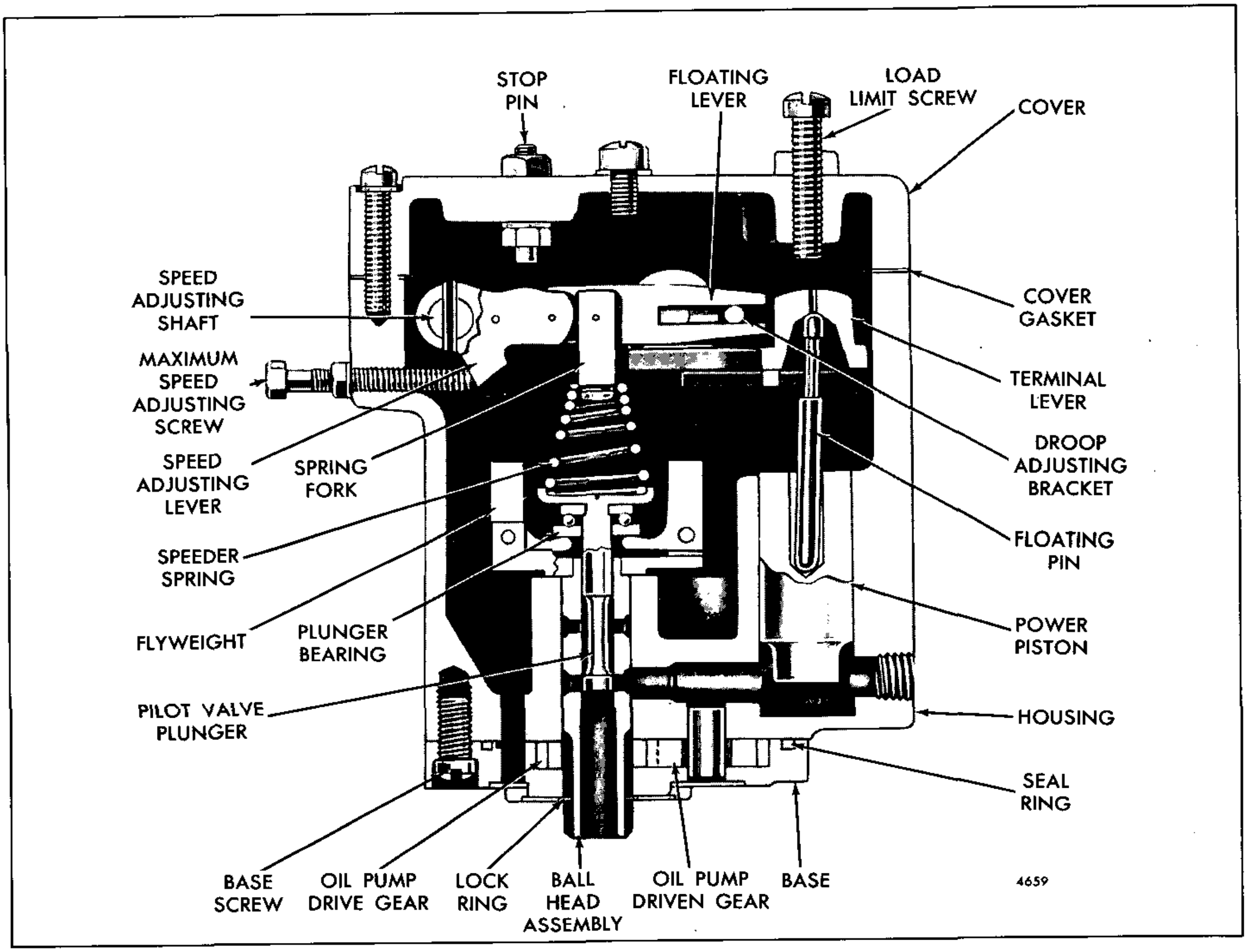


FIG. 1 – Hydraulic Governor Assembly (Current)

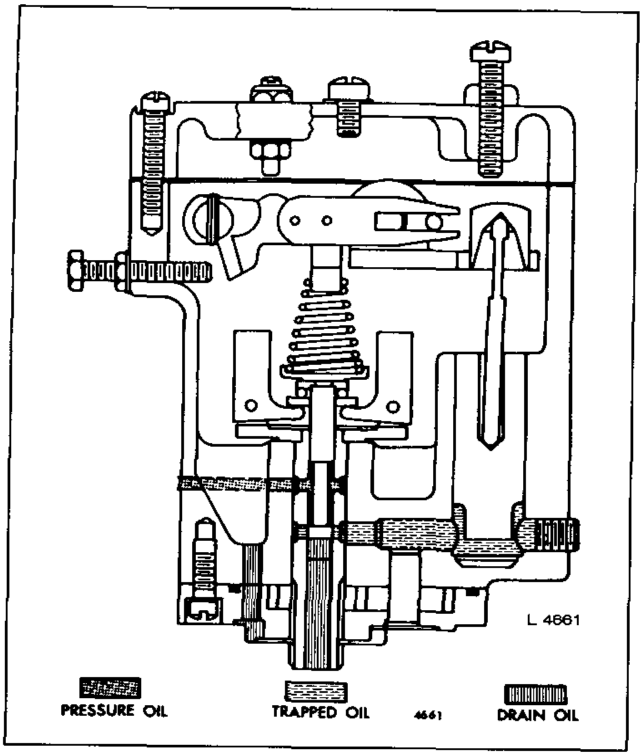


Fig. 2 – Stable Position of Governor Mechanism When Load on Engine is Constant

When starting a cold engine, it may require several cranking periods for the lubricating oil pressure to become great enough to operate the governor and open the throttle so the engine can start. Since such a delay in starting is considered objectionable, the starting time can be reduced by moving the throttle control terminal lever to the full–fuel position to take control of the injector fuel racks away from the governor.

The engine can be stopped, regardless of the governor, by moving the throttle control terminal lever to the no–fuel position. Considerable force must be exerted to do this as the oil pressure against the power piston must be overcome.

In addition to its function of holding the engine speed constant under varying load conditions, the hydraulic governor acts as an automatic shutdown device in case of lubricating oil pressure failure. Should the engine fail to supply oil to the governor, the servo–piston will drop, letting the fuel rod return to the no–fuel position, and shut down the engine.

The current governor housing incorporates integral speed adjusting and terminal shaft bosses with bushings. The separate speed adjusting sleeve, terminal sleeve and spacer cap used in the former housing have been eliminated. Also the size of the tapped hole in the lower passage of the housing was increased from 5/8" – 18 to 11/16" – 16 to accomodate the new relief valve components.

The current servo–piston is shorter and the new terminal lever is actuated by a floating pin assembled between the piston and the lever. The lever cross pin actuates the fuel rod mechanism. The former lever was actuated by direct piston contact and the lever actuated the fuel rod mechanism by direct contact with the fuel rod collar.

The current adjusting shaft and lever are pinned and supported by the bushings in the housing. The former shaft was serrated at the speed adjusting lever end.

The current idler gear stud has drilled passages for supplying oil, under pressure, to the inner diameter of the current idler gear. Formerly the drilled oil passages were in the idler gear.

Operation

As the engine operates, oil from the lubricating system is admitted to the gear pump in the governor base. The governor gear pump raises the oil pressure to a value determined by the spring in the relief valve assembly opposing the relief valve plunger. The oil, now under pressure, is maintained in the annular space between the small diameter of the pilot valve plunger and the bore in the ballhead as shown in Fig. 2. For any given throttle setting, the speeder spring has a definite compression force which is opposed by the centrifugal force of the flyweights. When these two forces are in equilibrium, the land on the pilot valve plunger exactly covers the lower ports in the ballhead producing the constant speed condition as shown in Fig. 2.

As a load increase is applied to the engine, the engine speed will drop and the governor flyweights will be forced inward, lowering the pilot valve plunger. Oil under pressure of the pump will now be admitted underneath the power piston which will rise. Upward movement of the piston is transmitted by the floating pin through the terminal lever and fuel rod to the injector control racks, causing the fuel setting of the engine to be increased as shown in Fig. 3.

As the power piston and terminal lever rise, the compression load on the speeder spring is reduced, allowing the flyweights to move out to their normal vertical position.

With the governor weights in a vertical position, the land on the pilot valve plunger will again cover the ports in the ballhead, trapping the regulating oil under the power piston. With the power piston held in its new position by the trapped regulating oil, the engine will carry the increased load at a slightly reduced speed.

Figure 4 illustrates the governor reaction as the load on the engine is decreased and the engine speed increases.

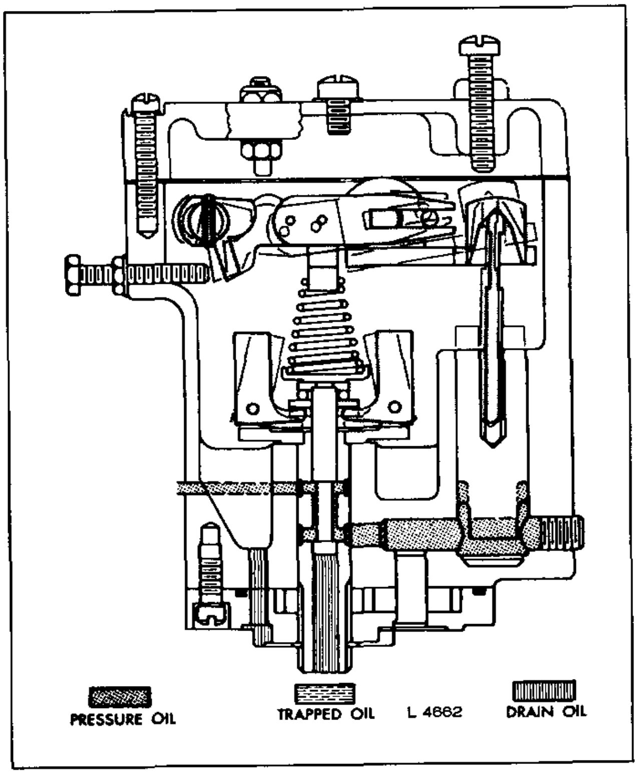


Fig. 3 – Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

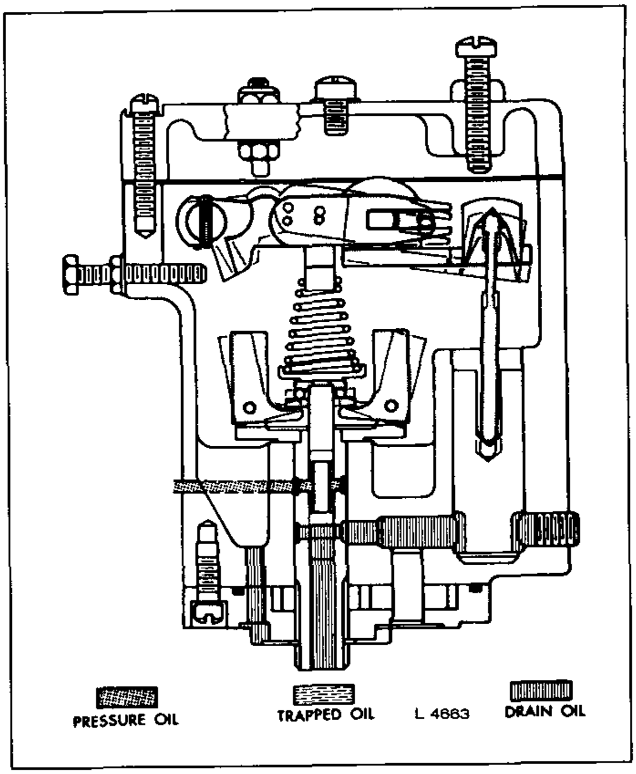


Fig. 4 – Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

Lubrication

The governor is lubricated by oil seeping into the governor housing past the power piston and the pilot valve plunger. Oil which collects on the floor of the governor drains into the gear drive beneath the governor. After reaching a certain level in the governor drive housing, the oil returns to the crankcase through a cored passage in the governor drive housing.

Remove Governor

Refer to Figs. 1, 5 and 6 and remove the governor as follows:

1. Remove the throttle control terminal lever retracting spring from the terminal lever.
2. Disconnect the fuel rod from the throttle control terminal lever.
3. Remove the nut and lock washer securing the throttle control rod assembly to the throttle control lever.
4. Disconnect the oil inlet tube assembly from the governor oil inlet plug.
5. On a governor equipped with a synchronizing motor, tag and disconnect the wires from the motor.
6. Remove the four bolts and lock washers securing the governor assembly to the governor drive housing and remove the governor assembly and gasket.

Disassemble Governor

Before removing any parts from the current governor, wash the unit thoroughly in clean fuel oil, dry it with compressed air and inspect it for worn or damaged parts that may be repaired or replaced without completely disassembling the governor.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Governor disassembly need be carried out only as far as necessary to correct the difficulties which interfere with proper governor operation.

Refer to Figs. 1, 6 and 10 for the location of the various parts and disassemble the governor as follows:

1. Note and record the position of the throttle control lever on the speed adjusting shaft. Loosen the bolt securing the lever to the shaft, then slide the lever off the shaft.

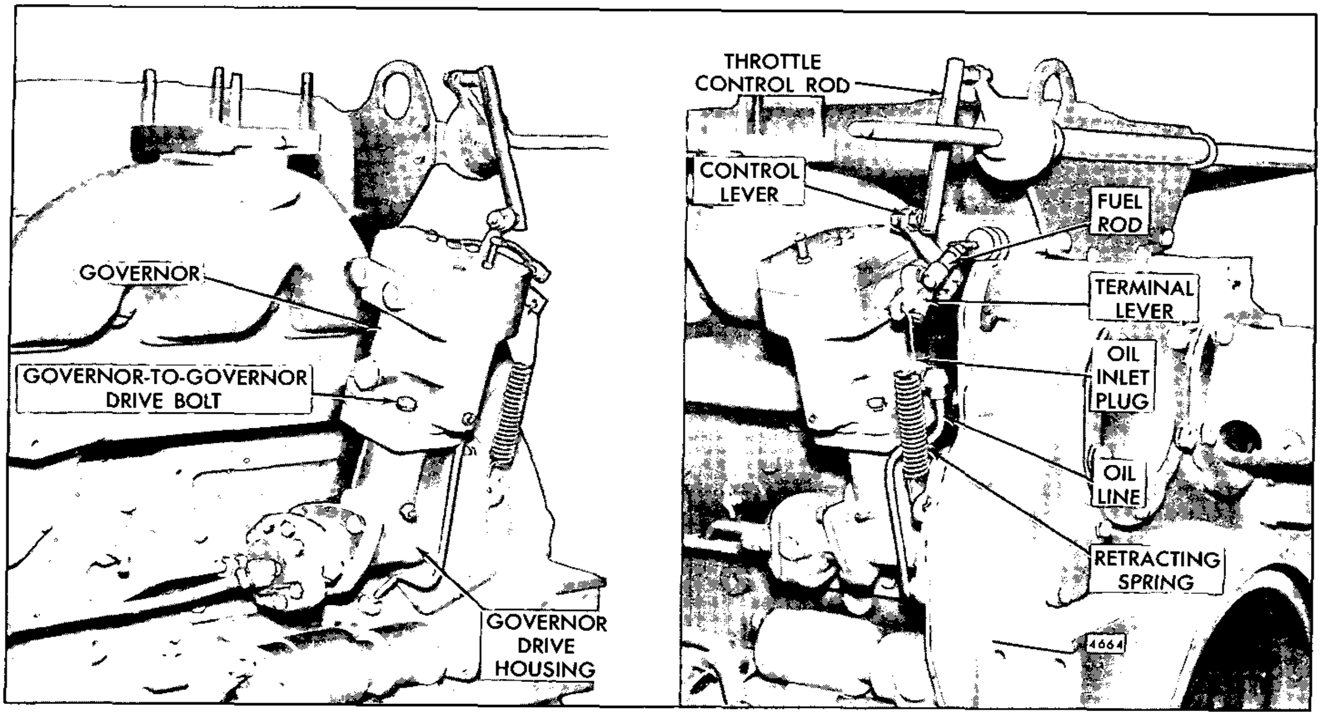


Fig. 5 – Hydraulic Governor Mounting

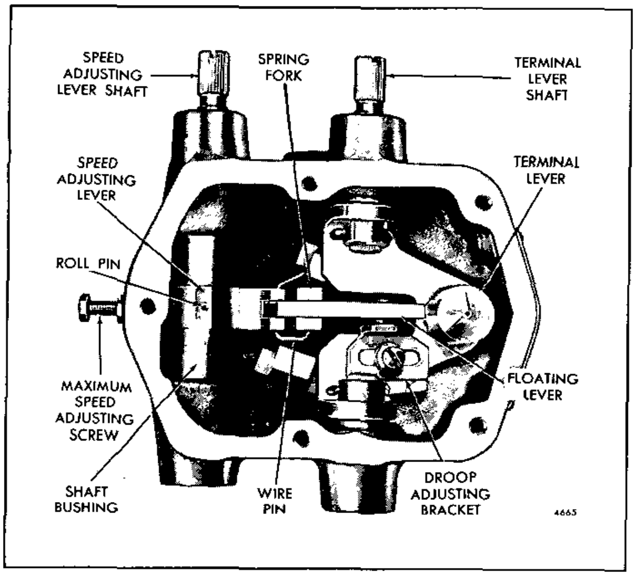


Fig. 6 – Top View of Governor With Cover Removed

2. Note and record the position of the throttle control terminal lever on the governor terminal lever shaft. Loosen the bolt securing the lever to the shaft, then slide it off the shaft.

3. If necessary, remove the oil inlet elbow from the governor housing oil inlet plug.

4. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws (Fig. 7).

5. On a governor equipped with a synchronizing motor, remove the end of the speed adjusting lever retracting spring from the hole in the side of the speed adjusting lever, using a pair of small nose pliers.

6. Remove the three cover screws, then remove the cover and gasket from the housing.

7. Loosen the maximum speed adjusting screw lock nut and remove the adjusting screw from the governor housing. *If the maximum speed adjusting screw is not removed, the speed adjusting lever spring pin will hit the screw when it is being removed from the adjusting lever.*

8. Remove the speed adjusting lever roll (spring) pin from the speed adjusting lever and the lever shaft with a small punch and hammer as shown in Fig. 7.

9. Note and record the position of the groove in the outside diameter of the speed adjusting lever shaft to ensure the groove will be installed in the same position at the time of assembly. Then pull the shaft out of the speed adjusting lever and the governor housing.

10. Remove the speed droop adjusting bracket screw, lock washer and plain washer from the terminal lever; then remove the droop adjusting bracket from the speed adjusting floating lever and the terminal lever.

11. Lift the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger as an assembly from the governor housing as shown in Fig. 8.

12. Remove the pilot valve plunger thrust bearing and the roll spring pin from the governor housing.

13. On a governor equipped with a synchronizing motor, slide the speed adjusting lever retracting spring off of the speed adjusting shaft bushing and remove it from the housing.

14. If necessary, the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger and spring seat assembly may be disassembled as follows:

    a. Straighten the bent end of the wire pin securing the speed adjusting lever and spring fork to the speed adjusting floating lever.

    b. Pull the pin out of the speed adjusting lever, floating lever and spring fork with a pair of pliers.

    c. Insert a small screw driver between the spring and fork and pry the speeder spring from the spring fork.

    d. Work a small screw driver around under the speeder spring and remove the spring from the pilot valve plunger and spring seat assembly.

15. Remove the two cotter pins securing the terminal lever to the terminal lever shafts.

16. Place a 1/4" brass rod, approximately 5" long, against the inner end of the terminal lever shaft, then drive the governor housing cup plug out of the boss at the side of the housing as shown in Fig. 9.

    NOTICE: Use care when removing the cup plugs; do not damage the serrations inside the terminal lever with the rod.

17. Remove the remaining governor housing cup plug from the boss in the opposite side of the housing in the same manner as outlined in Step 16.

18. Push the terminal lever shafts out of the terminal lever and housing with the brass rod. Then lift the terminal lever out of the housing.

19. Remove the terminal lever–to–power piston pin from the piston.

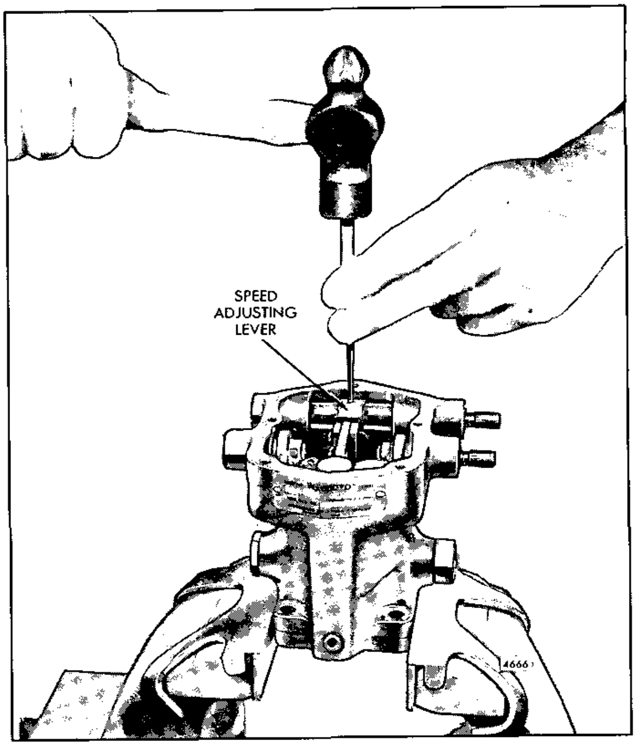


Fig. 7 – Removing Speed Adjusting Lever Roll Pin

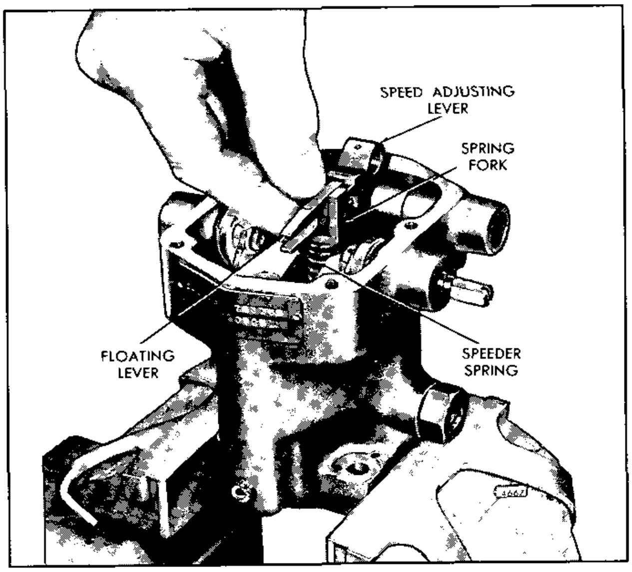


Fig. 8 – Removing Speed Adjusting Lever, Floating Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly

20. Remove the governor housing from the bench vise. Turn the governor upside down and remove the power piston from the housing. It may be necessary to tap the

face of the governor housing lightly against a wood block to jar the piston out of the housing.

21. Place the housing, bottom side up, on a bench.
22. Remove the lock ring from the groove in the shaft of the ball head with a pair of snap ring pliers, then remove the ball head and flyweight assembly from the housing.
23. Remove the three screws securing the governor base to the governor housing.
24. Tap the edge of the governor base lightly with a plastic hammer to loosen it, then remove the base and seal ring from the governor housing and dowel pins.
25. Remove the oil pump drive and driven gears from the governor base or housing.
26. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise.
27. Remove the oil inlet plug, gasket, relief valve plunger sleeve retaining spring and relief valve plunger spring from the governor housing.
28. Remove the dummy hole plug and gasket from the opposite side of the governor housing. Then insert a small brass rod through the dummy hole opening and push the relief valve plunger and the relief valve plunger sleeve out of the governor housing. Catch the plunger and sleeve by hand when removing them.

    The relief valve plunger incorporates a No. 8–32 thread to facilitate the removal of the plunger from the housing, if required, without removing and disassembling the governor.
29. If necessary, remove the speed adjusting lever shaft hole plug in the governor housing by inserting a 1/4" brass rod through the shaft opening and tap the cup plug out of the housing with a hammer.
30. If necessary, remove the speed adjusting shaft oil seal from the governor housing.

Inspection

Wash all of the governor parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the pilot valve plunger and its bore in the ball head for scoring and burrs. If slightly scored, the area may be cleaned up with a fine india stone. Care must be used to prevent rounding off the edges of the plunger.

Examine the oil pump gears and the driven gear bushing for excessive wear and damage.

Examine the power piston and its cylinder (bore) in the governor housing for scoring and burrs. If slightly scored, the areas may be cleaned up with a fine India stone. Care must be used to prevent stoning flat areas and rounding off the edges of the piston.

Examine the ends of the power piston–to–terminal lever pin for wear and scoring. If slightly scored, clean the ends up with a fine india stone. Also check the pin seats in the terminal lever and power piston for wear and scoring.

Examine the ends of the terminal lever cross pin and the holes in the terminal lever for wear and scoring.

Examine the outside diameter of the ball head and its bore in the governor housing for scoring and burrs. If slightly scored, the areas may be cleaned up with a fine india stone. Care must be used to prevent flat areas and rounding off tghe edges of the ball head.

The pilot valve plunger, power piston and ball head assembly must operate freely in their respective bores.

Examine the pilot valve thrust bearing for excessive wear and flat spots.

Inspect the finished radius (thrust bearing contact surfaces) of the flyweights for excessive wear or flat spots. The flyweights must operate freely on their support pins for satisfactory governor operation.

Inspect the terminal lever and speed adjusting lever shaft bushings in the governor housing. If scored or worn excessively, replace the bushings.

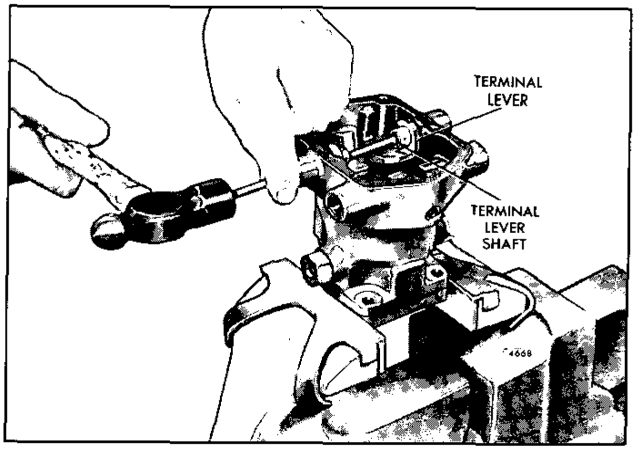


Fig. 9 – Removing Cup Plug from Governor Housing

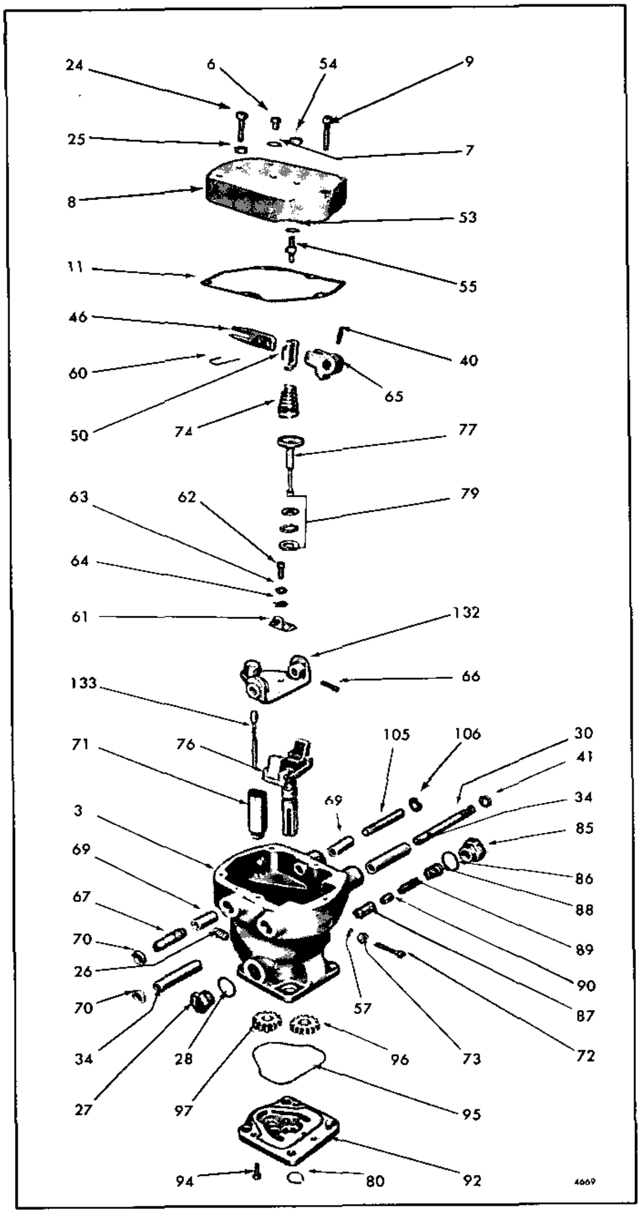


Fig. 10 – Hydraulic Governor Details and Relative Location of Parts

1. Screw—Load Limit
2. Screw—Cover Hole
3. Nut—Stop Pin
4. Screw—Cover
5. Copper Washer
6. Copper Washer
7. Pin—Speed Adjusting Lever Stop
8. Pin—Speed Adjusting Lever Roll
9. Lever—Speed Adjusting
10. Plunger—Pilot Valve
11. Bearing—Plunger
12. Lever—Terminal
13. Pin—Cotter
14. Shaft—Terminal Lever (Long)
15. Bushing—Terminal Lever Shaft
16. Seal—Terminal Lever Shaft Oil
17. Shaft—Speed Adjusting
18. Seal—Speed Adjusting Shaft Oil
19. Bushing—Speed Adjusting Shaft
20. Plug—Oil Inlet
21. Gasket—Plug
22. Spring—Sleeve Retaining
23. Spring—Relief Valve Plunger
24. Plunger—Relief Valve
25. Sleeve—Relief Valve Plunger
26. Screw—Maximum Speed Adjusting
27. Nut—Adjusting Screw
28. Copper Washer—Maximum Speed Adjusting Screw
29. Gear—Oil Pump Drive
30. Ring—Base to Housing Seal
31. Base—Governor
32. Lock Ring
33. Screw—Base to Housing
34. Gear—Oil Pump Driven
35. Gasket—Plug
36. Plug—Dummy Hole
37. Plug—Housing Cup
38. Plug—Housing
39. Shaft—Terminal Lever (Short)
40. Housing—Governor
41. Spring—Retracting (Syn. Motors Only)
42. Piston—Power
43. Ball Head Assy.
44. Pin—Terminal Lever to Piston
45. Bracket—Droop Adjusting
46. Lock Washer
47. Washer—Plain
48. Screw—Bracket
49. Spring—Speeder
50. Fork—Spring
51. Pin—Spring Fork Wire
52. Lever—Floating
53. Gasket—Cover
54. Cover—Governor
55. Nut—Load Limit Screw

Fig. 10 – Hydraulic Governor Details and Relative Location of Parts

Examine the relief valve plunger and the inside diameter sleeve for wear, scratches and sludge in the plunger the grooves and holes in the plunger and sleeve. The plunger in the former governors did not incorporate four relief holes and the sleeve and washer were separate pieces.

Inspect the bushings in the terminal lever and speed adjusting shaft sleeve in a former governor.

Check the speed adjusting lever retracting spring for fractured coils.

Replace all of the governor parts that are excessively worn or damaged.

Assemble Governor

Refer to Figs. 1 and 10 and assemble the current governor as follows:

1. If removed, install new speed adjusting lever and terminal shaft bushings in the governor housing to the specified dimensions shown in Fig. 11.
2. Lubricate the two oil pump gears and place them in their respective positions in the governor base.
3. Place a new seal ring in the groove of the governor base, with the wide side of the seal down in the groove.

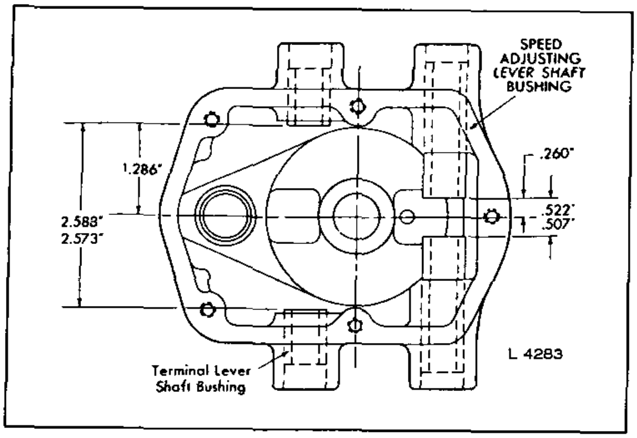


Fig. 11 – Location of Speed Adjusting Lever and Terminal Lever Shaft Bushings in Governor Housing

4. Set the governor housing on the base with the dowels in the base registering with the holes in the housing and the idler gear stud in the housing registering with the hole in the idler gear. Press the housing down against the base seal ring.

5. Lubricate the outside diameter of the ball head with engine oil; then insert the end of the ball head and flyweight assembly straight into and through the bore of the governor housing, drive gear and base.

   It is important when installing the driven gear stud that it be installed with the arrow on the stud pointing towards the relief valve side of the governor. Also, that the shaft of the arrow is parallel to a line through the center of the governor and the relief valve.

6. Insert three screws through the governor base and thread them into the governor housing. Turn the ball head assembly while tightening the screws to make sure the ball head assembly revolves freely.

   If a bind exists, loosen the screws, tap the sides of the base lightly with a plastic hammer and tighten the screws again. Revolve the ball head assembly again and check for bind. Repeat, if necessary, until all parts rotate freely.

   To install a current design governor base on a former design housing or a former design base on a current design housing, No. 3 taper dowel pins must be used. Refer to Fig. 12 for fabrication of tools necessary to properly align the base and the housing and proceed as follows:

   a. Position the dummy gear over the idler gear stud.

   b. Position the base against the governor housing and align them with the tapered arbor.

   c. Enlarge the dowel pin holes to .200"–.212" diameter and taper ream to allow for a No. 3 tapered pin. Always drill from the base to the housing and be sure the tapered pin is flush with the bottom of the governor mounting flange.

7. Install the ball head lock ring in the groove of the ball head shaft with a pair of snap ring pliers.

8. Refer to Fig. 13 and install the relief valve plunger, plunger sleeve, plunger retaining spring, sleeve retaining spring, oil inlet plug and dummy plug in the governor housing as follows:

   a. Lubricate the outside diameter of the relief valve plunger and plunger sleeve with engine oil. Then insert the relief valve plunger inside of the plunger sleeve.

   b. Determine the type of governor being assembled, right–hand or left–hand, then insert the relief valve plunger and sleeve assembly straight into the proper opening in the side of the governor housing, with the tapped hole in the relief valve plunger facing out, and push it in against the shoulder in the housing.

   c. Place the relief valve plunger spring and the plunger sleeve retaining spring in the housing and against the plunger and sleeve.

   d. Place a gasket on the oil inlet plug, then place the plug over the ends of the springs and thread it into the governor housing.

   e. Place a gasket on the dummy hole plug and thread it into the opening in the opposite side of the governor housing.

   f. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise. Then tighten the oil inlet plug and dummy hole plug securely.

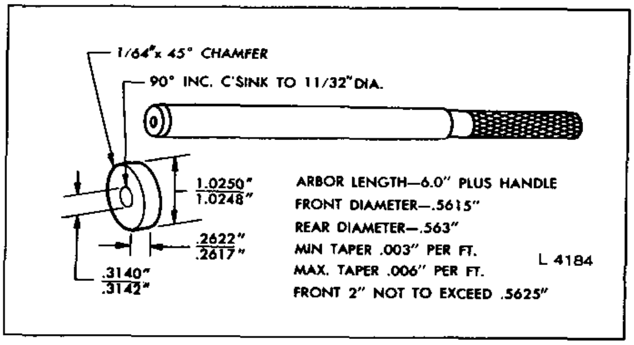


Fig. 12 – Fabrication of Governor Housing–to–Base Alignment Tool

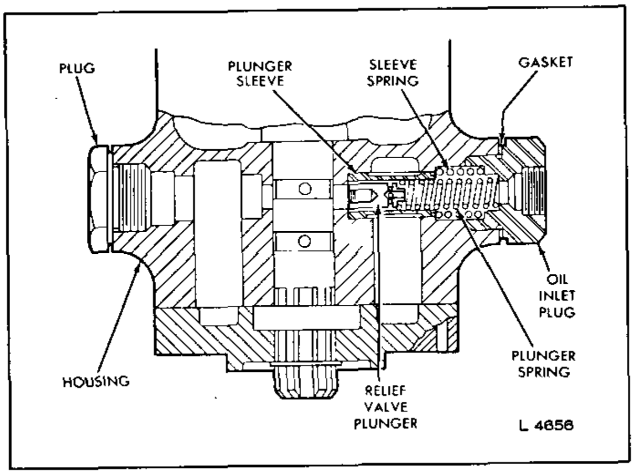


Fig. 13 – Location of Oil Relief Valve Plunger, Plunger Sleeve, Springs, Oil Inlet Plug and Dummy Plug in Governor Housing (R.H. Governor Shown)

9. Lubricate the power piston with engine oil, then insert the piston, small end down, straight into the piston bore in the governor housing and push it in until it bottoms.

10. Install the terminal lever, terminal lever shafts, cotter pins and cup plugs in the governor housing as follows:

    a. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

    b. Lubricate one of the terminal lever shafts with engine oil. Place the terminal lever in between the ends of the two bushings inside of the governor housing; then insert the serrated end of the shaft into the bushing in the housing with the cotter pin holes in the shaft and terminal lever in alignment as shown in Fig. 14. Push the shaft into the lever until the two holes are in alignment.

    c. Install a cotter pin through the terminal lever and shaft and bend the ends over against the side of the terminal lever.

    d. Install the second terminal lever shaft in the housing and terminal lever at the opposite side of the governor housing in the same manner as outlined in Steps b and c.

    e. Apply a thin coat of sealing compound to the outside diameter of a new governor housing cup plug. Start the plug, open end out, straight into one of the shaft openings, then press the plug in flush with the outside face of the housing boss.

    f. Install the second new governor housing cup plug in the boss at the opposite side of the housing in the same manner as described in Step e.

11. Lubricate the terminal lever–to–power piston pin with engine oil. Raise the edge of the terminal lever and insert the pin in the hole in the power piston, then lower the terminal lever down on the pin.

12. If disassembled, the speed adjusting lever, floating lever, spring fork, speeder spring and the pilot valve plunger may be assembled as follows:

    a. Place the non–slotted end of the speed adjusting floating lever in the slot on the speed adjusting lever so the pin holes are in alignment.

    b. Insert the long end of the speed adjusting lever–to–floating lever wire pin through the pin hole in the speed adjusting lever and floating lever.

    c. Place the speed adjusting floating lever in the slot of the spring fork with the pin holes in alignment, then insert the short end of the wire pin through the hole in the spring fork and the floating lever.

    d. Push the wire pin in against the speed adjusting lever and spring fork and bend the protruding end of the pin over toward the slotted end of the floating lever.

    e. Press the lower end of the spring fork into the small end of the speeder spring; then insert the opposite end of the spring in the spring seat of the pilot valve plunger.

13. Remove the governor housing from the bench vise and place it on its side, oil inlet plug side up, on a work bench with the top of the housing facing out.

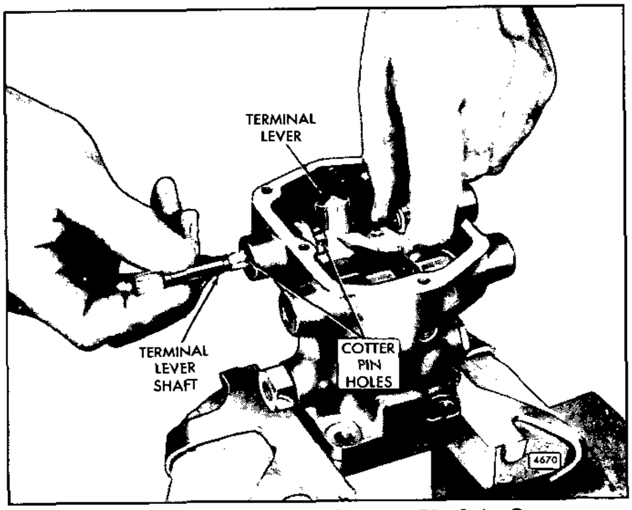


Fig. 14 – Installing Terminal Lever Shaft in Governor Housing and Terminal Lever

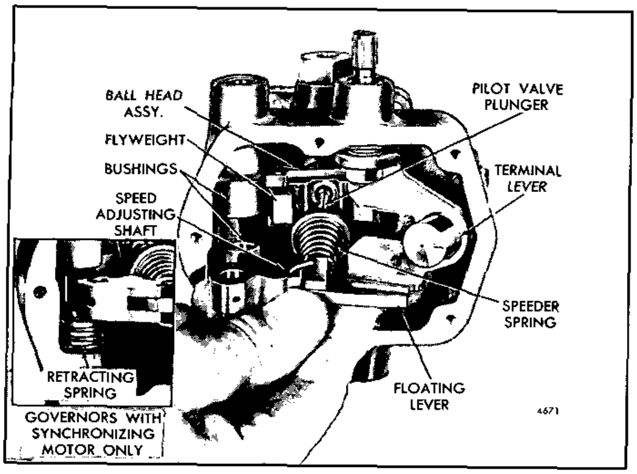


Fig. 15 – Installing Speed Adjusting Lever, Floating Lever, Speeder Spring and Pilot Valve Plunger Assembly

14. On a governor equipped with a synchronizing motor, place the speed adjusting lever retracting spring over the speed adjusting lever shaft bushing in the governor housing, with the hooked end of the spring over the slot between the two shaft bushings. See inset in Fig. 15.

15. Lubricate the pilot valve plunger thrust bearing with engine oil and place it over the end of the pilot valve plunger with the smallest, outside diameter, bearing race next to the spring seat.

16. Lubricate the pilot valve plunger with engine oil. Then hold the thrust bearing against the spring seat and insert the assembly in the governor housing with the speed adjusting lever facing the two bushings inside the housing (Fig. 10). Start the pilot valve plunger straight into the bore of the ball head and push the assembly in until the speed adjusting lever is in position between the two bushings and the thrust bearing is resting on the lip of the flyweights.

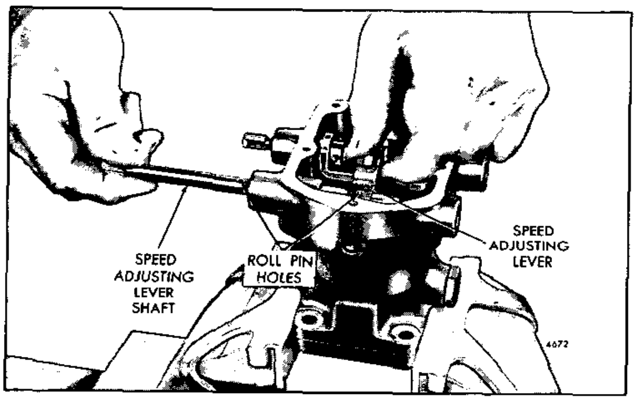


Fig. 16 – Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever

17. Install the speed adjusting lever shaft, roll (spring) pin and cup plug in the governor housing as follows:

    a. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

    b. Lubricate the speed adjusting lever shaft with engine oil. Rotate the shaft so the machined slot in the outside diameter of the shaft is in the same position it was in at the time of removal. Then insert the shaft in the shaft bushing in the housing, from the oil inlet plug side, with the roll pin hole in the shaft and lever in alignment (Fig. 16).

    c. While holding the speed adjusting lever, push the shaft through the bushing, lever and into the second shaft bushing until the pin holes are in alignment.

       On a governor equipped with a synchronizing motor, be sure the hooked end of the speed adjusting lever retracting spring is *on top of the speed adjusting lever* before installing the shaft (see inset in Fig. 15).

    d. Start the speed adjusting lever roll (spring) pin straight into the pin hole in the lever, then tap the pin through the lever and shaft until it is flush with the top of the lever.

    e. On a governor equipped with a synchronizing motor, rotate the speed adjusting lever retracting spring clockwise around the shaft bushing and insert the hooked end of the spring in the small hole in the side of the speed adjusting lever with a pair of small nose pliers.

    f. If removed, apply a thin coat of sealing compound to the outside diameter of the speed adjusting lever shaft cup plug. Start the plug, open end out, straight into the boss in the opposite side of the governor housing, then press the plug in flush with the edge of the boss.

    g. If removed, apply a thin coat of sealing compound to the outside diameter of the speed adjusting shaft oil seal. Place the oil seal, lip of seal facing in, over the end of the speed adjusting shaft and start it in the bore in the housing, then press the seal in flush with the edge of the boss.

18. Place the flat side of the speed droop adjusting bracket against the top (bolting) surface of the terminal lever, with the pin in the bracket in the slot of the speed adjusting floating lever. Secure the bracket to the terminal lever with a flat washer, lock washer, and screw.

19. If removed, thread the lock nut on the maximum speed adjusting screw. Place the copper washer on the adjusting screw, then thread the screw approximately half way in the governor housing.

20. If removed, place a copper washer over the threaded end of the speed adjusting lever stop pin. Insert the threaded end of the stop pin through the hole in the governor cover and secure it in place with a nut.

21. Affix a new governor cover gasket to the bottom face of the cover. Place the cover on the governor housing and secure it in place with the three screws with lock washers.

22. If removed, thread a lock nut on the load limit screw then thread it approximately half–way in the governor cover (Fig. 1).

23. Place the throttle control terminal lever on the governor terminal lever shaft in the same position it was in at the time of removal, then tighten the retaining bolt to 7–9 lb–ft (9.5–12.2 N·m) torque.

24. Place the throttle control lever with the throttle control rod assembly attached, on the speed adjusting lever shaft in the same position it was in at the time of removal, then tighten the retaining bolt to 7–9 lb–ft (9.5–12.2 N·m) torque.

25. If removed, install the oil inlet tube elbow in the oil inlet plug.

Install Governor

Refer to Fig. 5 and proceed as follows:

1. Affix a new gasket to the top of the governor drive housing.

2. Position the governor over the governor drive housing with the throttle control levers facing the rear of the engine. Turn the ball head assembly slightly to align splines of the ball head shaft with the splines in the driven shaft sleeve; then enter the shaft straight in the sleeve and rest the governor on the gasket.

3. Install the governor to drive housing bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.

4. Connect the oil inlet tube assembly to the oil inlet elbow.

5. Attach the throttle control rod assembly to the throttle control cross shaft lever.

6. Attach the fuel rod to the throttle control terminal lever.

7. Attach the throttle control terminal lever retracting spring to the terminal lever.

8. On a governor equipped with a synchronizing motor, connect the wires to the motor.

After the governor has been installed, the engine must be tuned–up as outlined under *Engine Tune–Up Procedures* in Section 14.

HYDRAULIC GOVERNOR DRIVE

The governor drive assembly (Fig. 1) consists of a horizontal drive shaft and bevel drive gear and a vertical driven sleeve and bevel driven gear mounted on ball bearings and contained in the governor drive housing.

A second ball bearing is mounted in the drive housing to support the drive gear end of the horizontal drive shaft and is retained in the housing by a snap ring.

The vertical driven gear, bearing and sleeve are retained in the governor drive housing by two conical set screws, copper washers and elastic stop nuts.

The horizontal drive shaft is driven by the governor drive gear which is keyed to and retained on the drive shaft by a self-locking nut and driven by either the camshaft gear or the balance shaft gear, depending upon the engine model.

The governor drive housing is attached to the forward face of the cylinder block end plate as shown in Fig. 2. The engine fuel pump is attached to the forward end of the drive housing and is driven by the governor drive shaft.

The governor is attached to the top of the governor drive housing and is driven through splines on the lower end of the ball head which register with splines in the upper end of the driven gear sleeve.

Lubrication

The governor drive beveled gears and bearings are lubricated by the surplus oil from the governor which spills over the moving parts inside of the drive housing. The surplus oil returns to the crankcase through a cored passage in the drive housing.

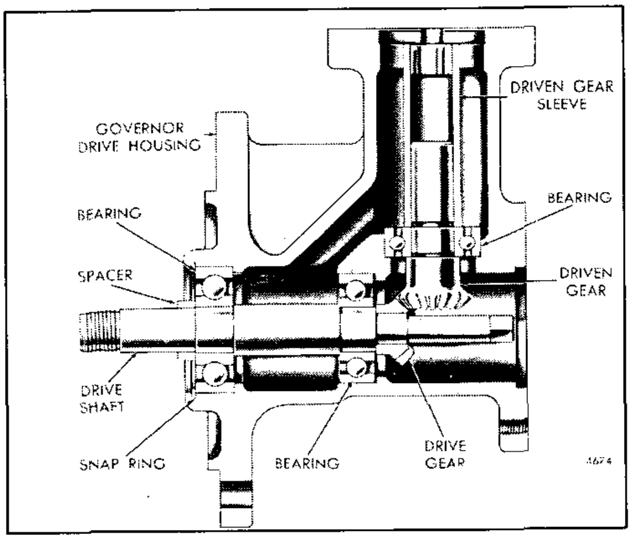


Fig. 1 – Hydraulic Governor Drive Assembly

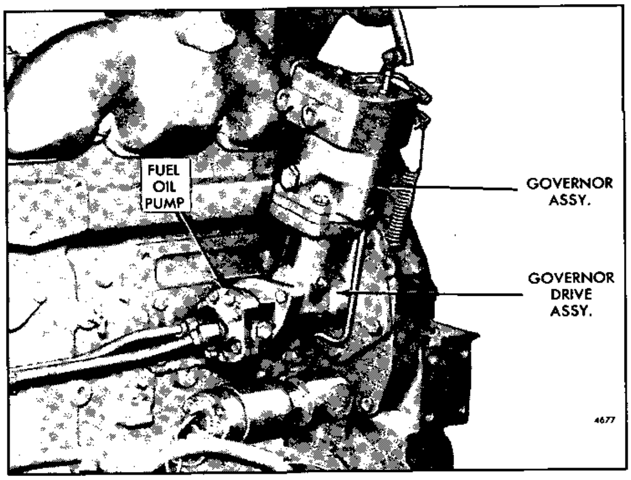


Fig. 2 – Hydraulic Governor Drive Mounting

Remove Governor Drive

Refer to Fig. 2 and proceed as follows:

1. Remove the governor as outlined under *Remove Governor* in Section 2.8.1.
2. Disconnect and remove the fuel oil inlet and outlet tube assemblies from the fuel oil pump.
3. Remove the three bolt and seal assemblies securing the fuel oil pump to the governor drive housing, then remove the pump, drive coupling and gasket.
4. Disconnect and remove the governor oil inlet supply tube from the elbow in the cylinder block under the governor drive housing.
5. Remove the three 3/8"–24 (12 pt. hd.) bolts and copper washers and the two 3/8"–16 (hex hd.) bolts and plain washers securing the governor drive housing to the cylinder block end plate.
6. If necessary, tap the side of the drive housing with a plastic hammer to loosen it, then remove the drive assembly and gasket from the end plate.

Disassemble Governor Drive

Refer to Figs. 1 and 3 and proceed as follows:

1. Clamp the governor drive gear in a bench vise equipped with soft jaws; then, remove the nut securing the drive gear to the governor drive shaft.
2. Clamp the bolting flange of the governor drive housing in a bench vise equipped with soft jaws. Attach a suitable gear puller to the governor drive gear and pull the gear from the drive shaft.

3. Remove the key from the keyway in the drive shaft. Also, slide the spacer off the end of the shaft.

4. Loosen the two driven gear bearing retaining set screw lock nuts (Fig. 3), then back the set screws out of the housing enough to free the bearing.

5. Pull the bevel driven gear, bearing and sleeve assembly out of the drive housing with a pair of small nose pliers.

6. Remove the governor drive shaft and ball bearing retaining snap ring from the groove in the drive housing with a pair of snap ring pliers.

7. Pull the drive shaft, bearing and drive gear assembly from the drive housing. If necessary, support the drive housing on the bed of an arbor press and press the drive shaft, bearings and drive gear assembly out of the drive housing.

8. Inspect the drive shaft and driven gear ball bearings as outlined under *Inspection*. If necessary, remove the bearings from the drive shaft and driven gear as follows:

   a. Place two plates between the bevel driven gear and the driven gear bearing; then, support the driven gear assembly and plates on the bed of an arbor press, with the driven gear over the opening in the bed of the press.

      The plates may be fabricated by drilling a 3/4" hole through the center of a 1/4" x 3" x 3" steel plate, then cutting the plate in half.

   b. Place a steel rod in the opening in the end of the driven gear sleeve and against the gear shaft; then, press the driven gear from the sleeve and bearing. Catch the driven gear by hand when pressed from the sleeve and bearing.

   c. Place the two plates around the drive shaft between the two bearings; then, support the drive shaft assembly and plates on the bed of an arbor press with the threaded end of the shaft facing up.

   d. Place a short brass rod on the end of the drive shaft and press the shaft out of the rear bearing. Catch the drive shaft, forward bearing and drive gear by hand when pressed from the bearing.

   e. Remove the drive gear and forward bearing from the drive shaft in the same manner as outlined in Steps c and d.

Inspection

Wash all of the governor drive parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the ball bearings for corrosion and pitting. Lubricate each bearing with engine oil; then, while holding the inner race from turning, revolve the outer race slowly by hand and check for rough spots.

Inspect the teeth of the drive and driven bevel gears for chipping, scoring or wear. Remove any slight score marks with a fine India stone.

Inspect the splines in the driven gear sleeve for wear. Also, the splines on the governor ball head for wear.

Examine the teeth of the governor drive gear for chipping, scoring or wear. Remove any slight score marks with a fine India stone.

Replace all of the governor drive parts that are excessively worn or damaged.

Assemble Governor Drive

Refer to Figs. 1 and 3 and proceed as follows:

1. Install the governor drive shaft bearings and drive gear on the drive shaft as follows:

   a. Lubricate the inside diameter of the forward drive shaft bearing with engine oil and start the bearing, numbered end up, straight on the small non–threaded end of the drive shaft.

   b. Place a suitable sleeve over the end of the drive shaft and against the inner race of the bearing. Then support the drive shaft, bearing and sleeve on the bed of an arbor press.

   c. Place a short brass rod on the end of the drive shaft and press the shaft straight into the bearing until the shoulder on the shaft is tight against the bearing inner race.

   d. Lubricate the inside diameter of the bevel drive gear with engine oil and start the gear straight on the small non–threaded end of the drive shaft.

   e. Place a brass plate, with a 1/2" hole through its center, over the end of the drive shaft and against the gear teeth. Then support the drive shaft, bearing, drive gear and brass plate on the bed of an arbor press.

   f. Place a short brass rod on the end of the drive shaft and press the shaft straight into the drive gear until the shoulder on the shaft is tight against the drive gear.

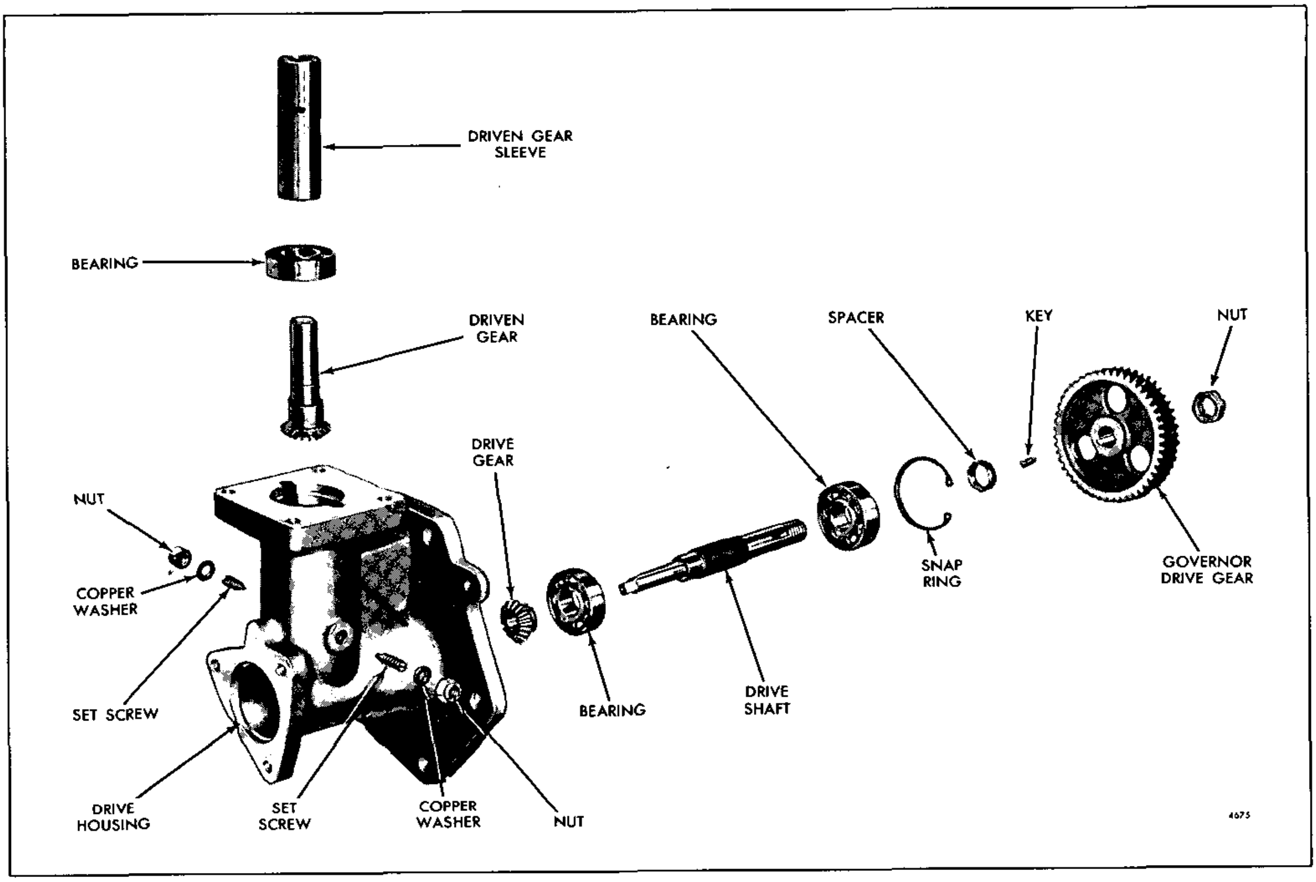


Fig. 3 – Hydraulic Governor Drive Details and Relative Location of Parts

g. Lubricate the inside diameter of the rear drive shaft bearing with engine oil and start the bearing, numbered end up, straight on the threaded end of the drive shaft.

h. Place a suitable sleeve over the end of the drive shaft and against the inner race of the bearing. Then support the drive shaft with bearings, drive gear and sleeve on the bed of an arbor press.

i. Place a short brass rod on the end of the drive shaft and press the shaft straight into the bearing until the shoulder on the shaft is tight against the bearing inner race.

2. Install the governor driven shaft bearing and sleeve on the driven gear as follows:

a. Lubricate the inside diameter of the driven gear bearing with engine oil and start the bearing, numbered end up, straight on the driven gear.

b. Place a suitable sleeve over the end of the driven gear and against the inner race of the bearing. Then support the driven gear and sleeve on the bed of an arbor press.

c. Place a short brass rod on the center of the driven gear and press the driven gear into the bearing until the shoulder on the gear is tight against the bearing inner race.

d. Lubricate the inside diameter of the driven gear sleeve with engine oil and start the non–splined end of the sleeve on the small end of the driven gear.

e. Support the driven gear with the bearing and sleeve on the bed of an arbor press with the teeth of the driven gear facing up.

f. Place a short brass rod on the center of the driven gear and press the driven gear into the sleeve until the end of the sleeve is tight against the bearing inner race.

3. Lubricate the two bearings on the drive shaft with engine oil. Insert the small end of the drive shaft into the drive shaft opening of the drive housing and start

the large drive shaft bearing straight into the bearing bore of the housing. Then guide the inner bearing into its bore and push the drive shaft assembly in the housing until the bearing contacts the shoulder in the housing.

4. Install the governor drive shaft and ball bearing retaining snap ring in the groove in the housing with a pair of snap ring pliers.

5. Lubricate the driven gear bearing with engine oil. Insert the driven gear, bearing and sleeve assembly in the opening in the top of the drive housing and start the bearing straight into the bearing bore in the housing. Then push the driven gear assembly in the housing until the teeth of the drive and driven gears are in mesh and the bearing is seated on the shoulder in the housing.

6. Install the two driven gear bearing retaining set screws with copper washers and nuts in the holes in the side of the drive housing. Turn the screws in tight against the bearing and tighten the lock nuts.

7. Install the governor drive gear on the governor drive shaft as follows:

   a. Place the governor drive shaft bearing spacer over the threaded end of the drive shaft and against the bearing inner race.

   b. Install the key in the keyway in the drive shaft.

   c. Lubricate the inside diameter of the governor drive gear with engine oil and start the gear on the drive shaft with the keyway in the gear in alignment with the key in the drive shaft.

   d. Support the governor drive housing assembly with the governor drive gear on the bed of an arbor press, with a support under the small outside diameter end of drive shaft.

   e. Place a suitable sleeve on top of the governor drive gear and under the ram of the press, then press the gear on the drive shaft and against the spacer.

   f. Clamp the governor drive gear in a bench vise equipped with soft jaws.

   g. Lubricate the threads of the governor drive gear retaining nut with engine oil. Thread the nut on the drive shaft and tighten the nut to 125–135 lb-ft (170–183 N·m) torque.

Install Governor Drive

Refer to Fig. 2 and proceed as follows:

1. Affix a new gasket to the bolting flange of the governor drive housing.

2. Place the governor drive assembly in position against the cylinder block end plate with the teeth of the governor drive gear in mesh with the teeth of the camshaft or balance shaft gear, depending upon the engine model.

3. Install 3/8″–24 bolts and copper washers in the three bolt holes in the drive housing (one at the bottom and two next to the cylinder block). Then install a 3/8″–16 bolt and plain washer in each of the two remaining bolt holes in the drive housing. Tighten the 3/8″–16 bolts to 30–35 lb-ft (41–47 N·m) torque and the 3/8″–24 bolts to 35–39 lb-ft (47–53 N·m) torque.

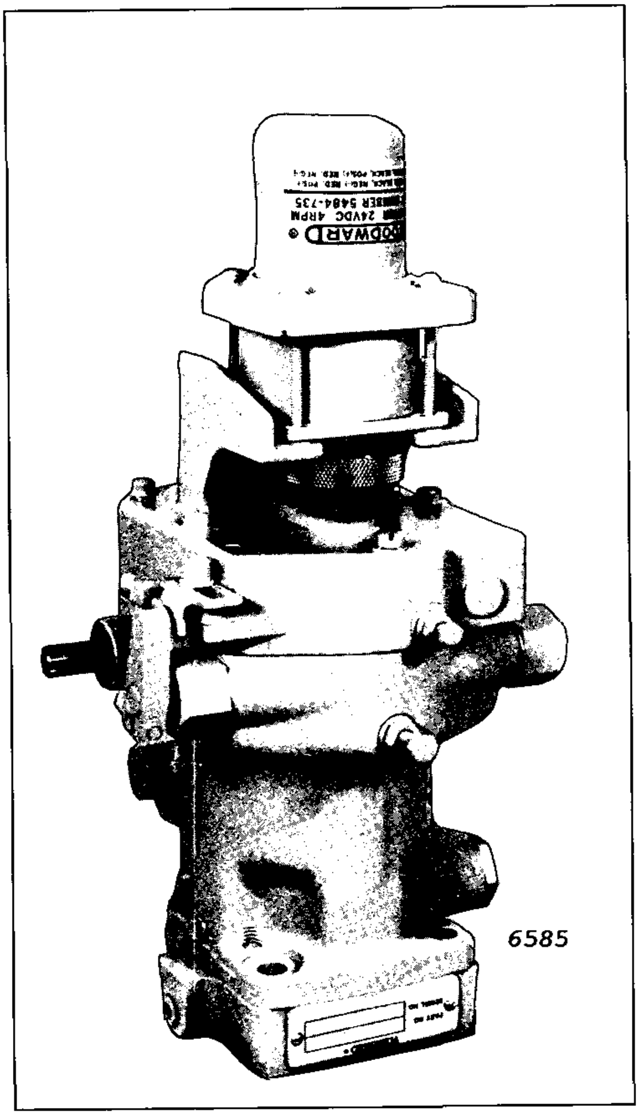
4. Affix a new gasket to the bolting flange of the fuel pump assembly. Place the fuel pump drive coupling over the square end of the fuel pump drive shaft, then place the fuel pump in position against the front face of the drive housing with the drive coupling over the square end of the governor drive shaft. Install the three bolt and seal assemblies and tighten the bolts to 13–17 lb-ft (18–23 N·m) torque.

5. Connect the fuel oil inlet and outlet tube assemblies to the fuel pump.

6. If removed, attach the governor oil inlet supply tube to the elbow in the cylinder block under the governor drive housing.

7. Install the governor on the drive housing as outlined under *Install Governor* in Section 2.8.1.

HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR



• Fig. 1 – Woodward Synchronizing Motor Mounting

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Fig. 1). This motor, used in place of a vernier control knob, permits close adjustment of the engine speed from a remote control point. This feature is especially valuable when synchronizing two generators from a central control panel.

• Bodine motors (Fig. 2) are mounted horizontally on the governor covers and use a 90 degree offset drive connected through a reduction gear on the motor and a friction drive.

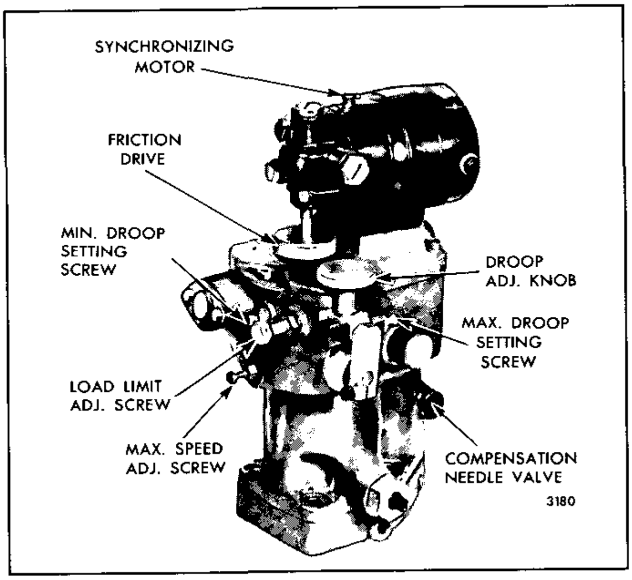


Fig. 2 – Bodine Synchronizing Motor Mounting

• Woodward motors (Fig. 1) are mounted vertically on the governor covers and connected to the governor speed adjusting shaft through a short gear train.

• A double pole, double throw switch is used to change the motor speed setting. Connect the switch to current motors as shown in Fig. 3.

Operation

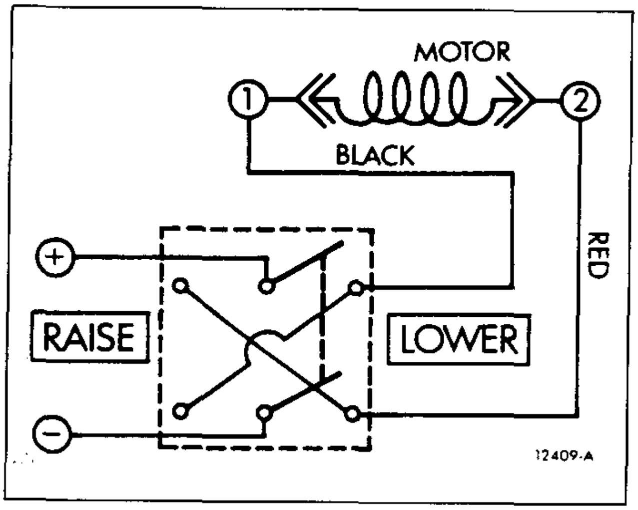
The synchronizing motor is used to change the engine speed when the unit is running alone, or to adjust the load when the unit is operating in parallel with other units. When the two–way control switch on the control panel is closed, the motor shaft turns the governor speed adjusting shaft by means of the reduction gear and friction drive. The direction of rotation (clockwise or counterclockwise) is dependent upon the position of the switch. When the desired engine speed is indicated on a tachometer or frequency meter on the control panel, the switch is returned to the *off* position by the operator.

If the switch is held in the *lower* speed position too long, the synchronizing motor will continue to lower the engine speed until it ultimately shuts the engine down. If the switch is held too long in the *raise* speed position, the motor will turn the governor speed adjusting shaft until it strikes the maximum speed adjusting screw, after which the friction drive will slip and the motor will continue to run at a slightly reduced speed without further effect.

Service

The synchronizing motor is constructed to render long satisfactory service. However, if the motor is damaged or fails to operate, replace the entire motor as an assembly.

The spring washer of the friction drive on the motor must be strong enough to permit the motor to carry the speed adjusting lever up against the maximum speed adjusting screw without slipping, yet it must be loose enough to slip after the lever contacts the screw.



• Fig. 3 – Synchronizing Motor Wiring Diagram

FUEL INJECTOR CONTROL TUBE

The fuel injector control tube assembly (Figs. 1 and 2) is mounted on the cylinder head (In–line and V–53 engines) and consists of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to the cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no–fuel position. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to Section 14 for positioning of the injector rack control levers.

Certain engines use spring–loaded injector control tube assembly (Fig. 3), similar to the above except it has a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector rack, whereas with the non–spring loaded two screw injector control tube this could not be done. The above also permits the use of an air inlet housing with no emergency air shutoff valve as is required in some applications.

Do not replace the spring–loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shutoff valve. However, when the spring–loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to .6290" and install a 5/8" cup plug at each end of the housing.

Engine shutdown (normal or emergency) is accomplished on the spring–loaded fuel injector control tube (one screw design) by pulling the governor shutdown lever to the no–fuel position. With the two screw design injector control tube and lever assembly, emergency engine shutdown is accomplished by tripping the air shutoff valve in the air inlet housing. Normal shutdown is accomplished by pulling the governor shutdown lever to the no–fuel position. Adjustment of the single screw and locknut on each injector rack control lever can be performed the same as for the two screw design rack control lever as outlined in Section 14.

Remove Injector Control Tube

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.
2. Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

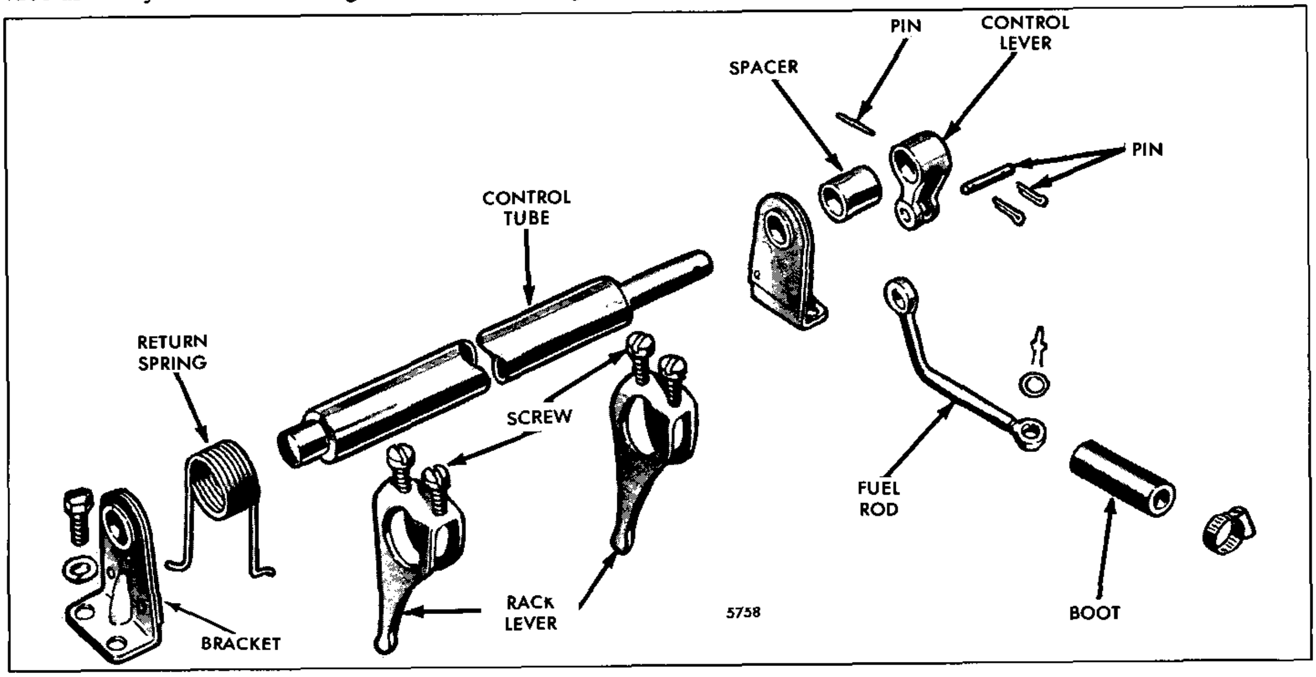


Fig. 1 – Injector Control Tube Assembly (Non–Spring Loaded – In–line Engine)

Disassemble Injector Control Tube

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:

1. Remove the bracket from the injector control tube.
2. Loosen the adjusting screws or adjusting screw and locknut at each injector rack control lever.
3. With the spring-loaded injector control tube, disconnect the yield springs at each rack lever, then roll the yield springs out of the slots and notch of the control tube.
4. Disconnect the return spring from the bracket and front or rear rack lever.
5. Then, remove the yield springs and/or return spring and rack levers from the control tube.

Inspection

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them, if necessary. The bearing in the bracket is not serviced separately. Examine the yield springs and/or return spring and replace them if worn or fractured.

Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1, 2 or 3 and assemble as follows:

IN-LINE ENGINE CYLINDER HEAD

1. **Two Screw design injector control tube.** Install the rack control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

   One Screw and Locknut design injector control tube. Install the rack control levers with the levers facing the front bracket position and R.H. helix yield springs. Then, install the odd (L.H. helix) yield spring and rack control lever with the lever facing the front bracket position.

   Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R.H. helix yield springs) in the control tube. Then, turn the adjusting screws and locknuts into the notch and slots far enough to position the levers on the control tube.

2. On both designs, install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the front bracket.

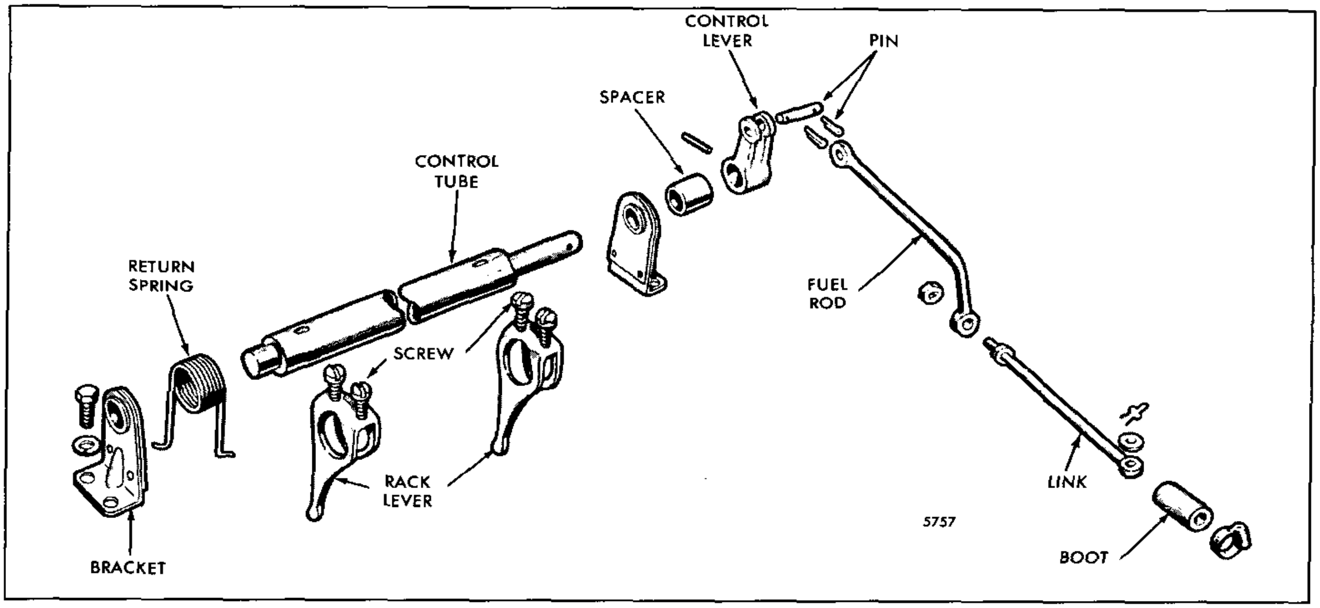


Fig. 2 – Injector Control Tube Assembly (Non-Spring Loaded – V Engine)

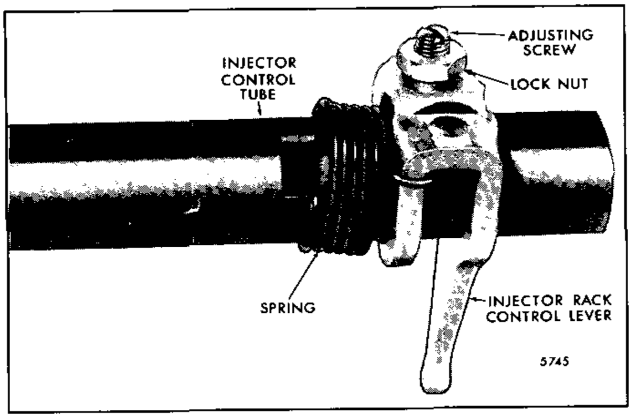


Fig. 3 – Injector Control Tube and Rack Lever (Spring-Loaded)

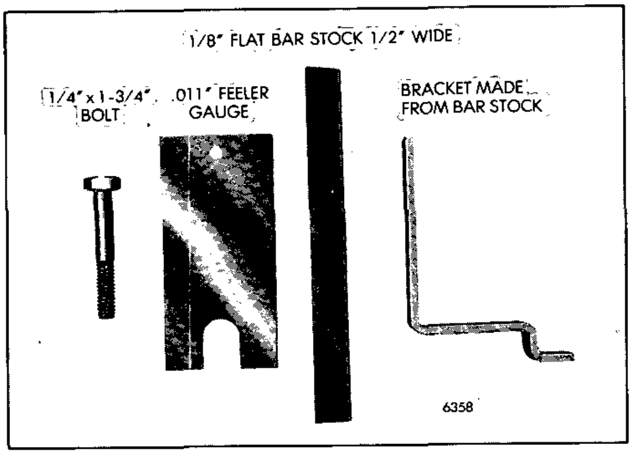


Fig. 4 – Fabricate Indexing Bracket

LEFT BANK V–ENGINE CYLINDER HEAD

1. Install the return spring on the control tube and against the front bracket.

2. **Two Screw design injector control tube.** Install the rack control levers on the control tube, with the levers facing the rear bracket position, and turn the adjusting screws in far enough to position the levers on the control tube.

   One Screw and Locknut design injector control tube. Install a rack control lever, with the lever facing the rear bracket position, and the odd (L.H. helix) yield spring. Then, install the R.H. helix yield springs and rack control levers with the levers facing the rear bracket.

   Attach the curled end of the yield springs to the rack control levers and roll the yield springs into the notch (odd spring) and slots (R.H. helix springs) in the control tube. Then, turn the adjusting screws and locknuts into the slots far enough to position the levers on the control tube.

3. Attach the curled end of the control tube return spring to the rack control lever and the extended end of the spring behind the rear bracket.

4. Install the front bracket on the end of the injector control tube.

RIGHT BANK V–ENGINE CYLINDER HEAD

1. **Two Screw design injector control tube.** Install the rack control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

   One Screw and Locknut design injector control tube. Install the rack control levers, with the levers facing the front bracket position and the R.H. helix yield springs. Then, install the odd (L.H. helix) yield spring and rack control lever, with the lever facing the front bracket position.

   Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R.H. helix yield springs) in the control tube. Then, turn the adjusting screws and locknuts into the notch and slots far enough to position the levers on the control tube.

2. Install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the front bracket.

Indexing a New Replacement Control Lever to the Injector Control Tube

Use the following procedure to properly index and install a replacement control lever onto the injector control tube:

1. Remove the injector control tube from the engine. Then, loosen the adjusting screw for the rack lever closest to the control lever and slide the return spring and rack lever back 3 to 4 inches.

2. Fabricate an indexing bracket from a 5" long piece of 1/2" wide, 1/8" thick bar stock (Fig. 4). Secure the indexing bracket to the control tube with a hose clamp (Fig. 5).

3. Insert a 1/4" x 1–3/4" L. bolt through the end of the control lever. Rotate the bracket and clamp until the bracket is resting against the bolt. Tighten the clamp to hold the bracket securely against the bolt. Make sure the indexing bracket cannot be moved.

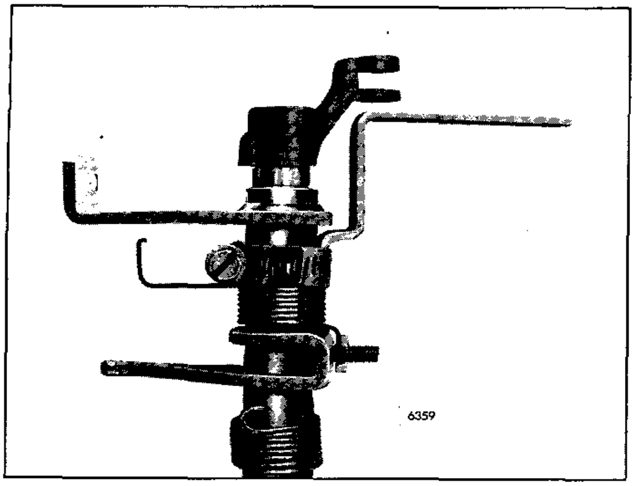


Fig. 5 – Secure Indexing Bracket to Control Tube

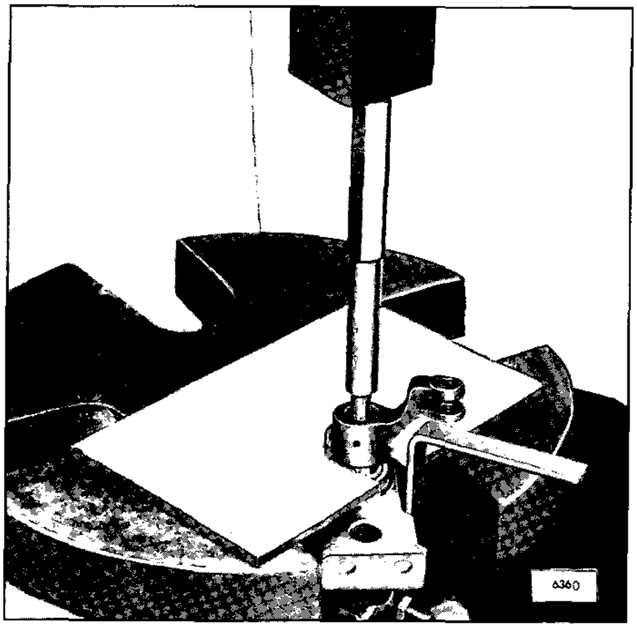


Fig. 6 – Press Old Lever off Control Tube

4. Remove the pin from the control lever and press the old lever off the control tube (Fig. 6).

5. *Reinsert the 1/4" x 1-3/4" L. bolt through the end of a* new lever and press the lever onto the control tube with the bolt resting against the indexing bracket (Fig. 7). Place a .011" feeler gage under the lever to get proper clearance between the lever and the spacer on the control tube. Before pressing on the lever, make sure the opposite end of the control tube is supported.

6. Position the control tube on the table of a drill press and drill a /8" hole through the control lever approximately 45° from the location of the former hole. (Use the replaced lever for reference). After drilling, install a new pin.

7. Clean the control tube thoroughly and install on the engine. Adjust the injector racks as outlined in Section 14.3.

Install Injector Control Tube

1. Engage the injector rack control levers with the injector control racks and place the brackets over the mounting holes on the cylinder head.

2. Install the two 1/4"–20 x 5/8" bolts and lock washers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 10–12 lb–ft (14–16 N·m) torque.

3. Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.

4. Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.

5. Refer to Section 14 and position the injector rack control levers. *Be sure the injector rack control levers can be placed in a no–fuel position before restarting the engine.*

CAUTION: Loss of shutdown control could result in a runaway engine which could cause personal injury.

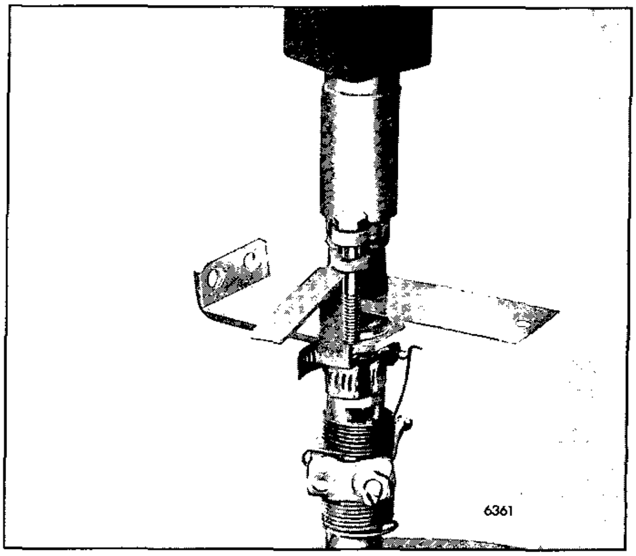


Fig. 7 – Installing New Lever

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INJECTOR TESTER J 23010-B

CAUTION: The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.

Use injector test oil J 26400 in the injector tester.

Installing Fuel Injector in Tester

1. Select the proper clamping head (Fig. 1). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 2).
2. Connect the test oil delivery piping into the clamping head.
3. Connect the test oil clear discharge tubing onto the pipe on the clamping head.
4. Locate the adaptor plate on top of the support bracket by positioning the 3/8" diameter hole at the far right of the adaptor plate onto the 3/8" diameter dowel pin. This allows the adaptor plate to swing out for mounting the fuel injector.
5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 1).
6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

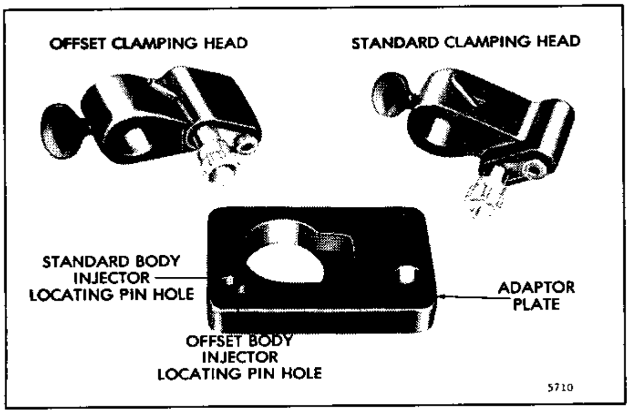


Fig. 1 - Injector Tester J 23010-A Clamping Heads

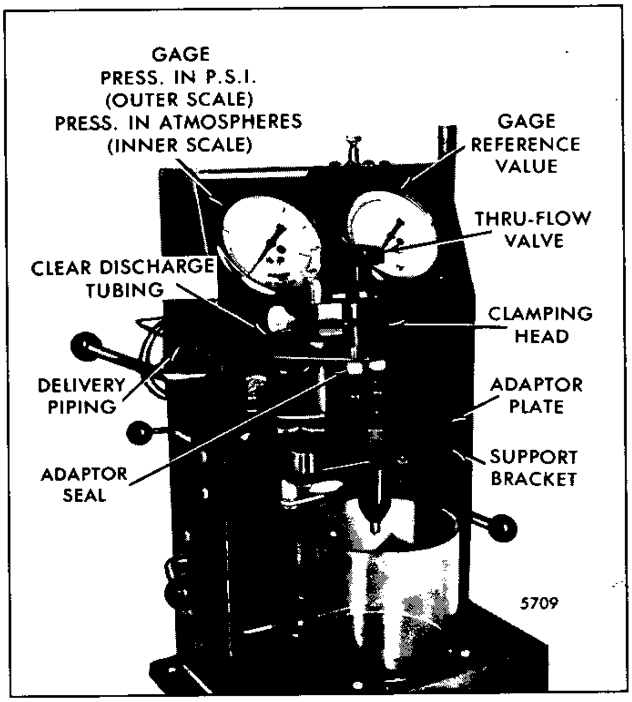


Fig. 2 - Injector Installed in Tester J 23010-A with Clamping Head

Clamping the Fuel Injector

1. Refer to (Fig. 3) and position the injector tester levers as follows:

   Lever 2 up and to the rear

   Lever 3 in the rear detent

   Lever 4 up (horizontal)

   Lever 5 up (horizontal)

2. Align the clamping head seals over the injector filter caps (Fig. 2).
3. Back off the Thru-Flow valve about half-way to allow the self-aligning fuel connector adaptors to seat properly during the clamping operation.

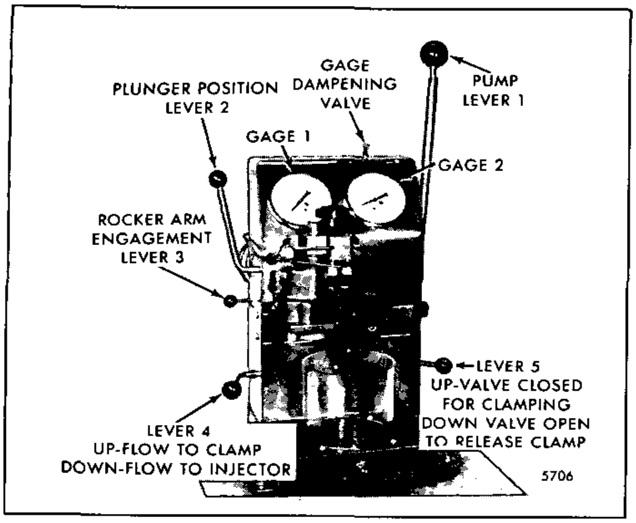


Fig. 3 – Injector in Position for Testing with J 23010–A

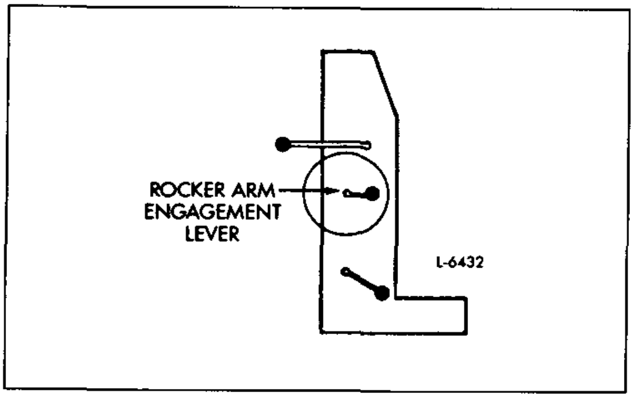


Fig. 4 – Position of Rocker Arm Engagement Lever

4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head *down* to seal the filter caps. The Thru–Flow valve should still turn freely. If it does not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.

NOTICE: Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

Purging Air from the System

Move lever 4 down and operate pump lever 1 to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

Check the injector for leaks as follows:

1. Operate pump lever 1 until gage 1 slowly reaches 100–200 psi (689–1378 kPa). Check for injector nut seal ring leaks. Then, increase gage reading to 1500–2000 psi (10 335–13 780 kPa). Cheek for leaks at the filter cap gaskets and the body plugs.
2. Note the time for the pressure to drop from 1500 psi to 1000 psi (10 335 kPa to 6890 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.

Injector Valve Opening, Atomization and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the valve opens and injection begins.

1. Position the injector rack in the *full–fuel* position.
2. Place pump lever in the *vertical* position.
3. Move the rocker arm engagement lever to the forward detent (Fig. 4).
4. Turn the gage damping valve knob (Fig. 3) clockwise to the *closed* position, then open the vlave slightly to control the rate of return of the gage hand. This valve is deleted on the current testers.
5. Operate the pump lever uniformly and observe the spray pattern produced.

Some experimentation may be necessary to determine the most effective rate at which the injector should be stroked. The correct rate is the one that produces the highest gage reading, too fast or too slow will give low readings.

The highest pressure indication will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector (138 Min. – 162 Max.).

The reference values obtained when pop testing the needle valve injectors are to be used as a troubleshooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the needle valve tip test using the J 23010–A tester and tip tester adaptor on the J 22640 auxiliary tester.

Unclamping the Injector

1. Open the Thru–Flow valve to release pressure in the system.
2. Move lever 5 *down* to release the clamping pressure.
3. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.
4. Carefully, return lever 5 to the *up (horizontal)* position.

CHECKING INJECTOR TESTER J 23010–B OR J 9787

The injector tester J 23010–B or J 9787 should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787–49.

Fill the supply tank in the injector tester with clean injector test oil J 26400. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block, then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400–2500 psi (16 536–17 225 kPa.) Close the valve on the fuel supply line. After a slight initial drop, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally, dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When the above occurs, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condition. Otherwise, the pump check valve must be removed, lapped and cleaned, or replaced (J 9787). The pump check valve in J 23010–A must be replaced.

If an injector tester supply or gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered, i.e. by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

INJECTOR SPRAY TIP TESTER (J 22640–A)

Valve Opening, Spray Pattern and Atomization.

1. Operate the pump handle until a clear flow of test oil is obtained at the tip mounting pedestal.

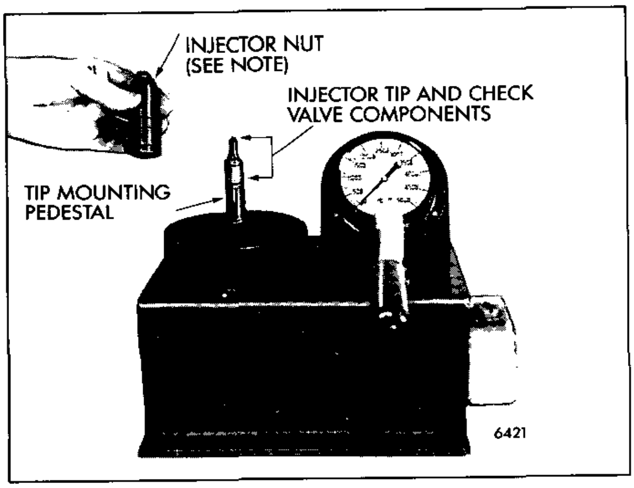


Fig. 5 – Installing Injector Nut

2. Place the tip assembly, valve spring with cage and check valve cage on top of the pedestal. Tighten the injector nut (Fig. 5).

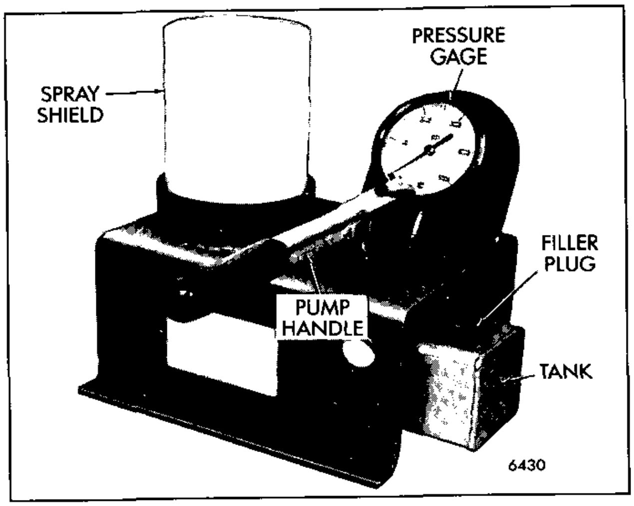


Fig. 6 – Tester J 22640–A with Shield Installed

3. Place the shield on the tester and operate the pump handle until the needle valve has opened several times to purge air from the system (Fig. 6).

CAUTION: Do not operate the tester without the shield. The fuel spray can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.

4. Operate the pump lever rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine. Note the pressure at which the test oil delivery occurs. Test oil delivery should occur between 2200 and 3300 psi (15 158 and 22 737 kPa). When using the high V.O.P. spring, the oil delivery will occur at 2900–3900 psi (19 981–26 871 kPa). The beginning and ending of delivery should be sharp and the test oil should be a finely atomized spray.

If the valve opening pressure is below the minimum specified limits or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within specified limits, proceed to check for spray tip leakage as follows:

When testing for spray tip leakage, be sure to use the proper spring for the valve tip being tested.

a. Actuate the pump lever several times and hold the pressure at 1500 psi (10 335 kPa) for 15 seconds.

b. Inspect the spray tip for leakage. There should be no fuel droplets, although a slight wetting at the spray tip is permissable.

Field Modification Kit (J 22640–51) consists of a pump and reservoir with hardware which is used to convert auxiliary tester J 22640 to J 22640–A. Tester J 22640 was previously connected to the pump of the pop stand.

INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

Flow gage J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

Field Modification Kit (J 25600–103) upgrades plunger and bushing/tip flow gage J 25600 to J 25600–A. The kit includes adaptors for Series 53 plunger and bushings. A newly designed spray tip receiver/holder is included with the kit along with instruction decals to be applied to the tester. This kit greatly upgrades the function of J 25600 by improving operation and repeatability.

CHECK INJECTOR OUTPUT

Perform the injector fuel output test in calibrator J 22410–A (Fig. 7).

1. Before testing injector output, be sure calibrator test oil is supplied to the injector fitting located over the rack. To change the flow from the calibrator, exchange the positions of the braided and the clear fuel lines (Fig. 8).

2. Place the cam shaft index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch to preheat the test oil to 95–105°F (35–40°C).

3. Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then, slide the adaptor forward and up against the fuel block face.

4. Place the injector seat J 22410–226 into the permanent seat (cradle handle in the *vertical* position). Clamp the injector into position by operating the injector clamp–up valve.

Set the counter (Fig. 9) at the appropriate number of strokes, 500 or 1,000. If for any reason this setting has been altered, reset the counter for the correct number of strokes. Calibrators with Serial No. 1175 or lower were manufactured as 1,000 stroke machines, but may have been converted to 500 stroke machines with a conversion kit (J 22410–516). Refer to the calibrator instruction manual for information on setting the counter and any additional information required.

5. Pull the injector rack out to the *no–fuel* position.

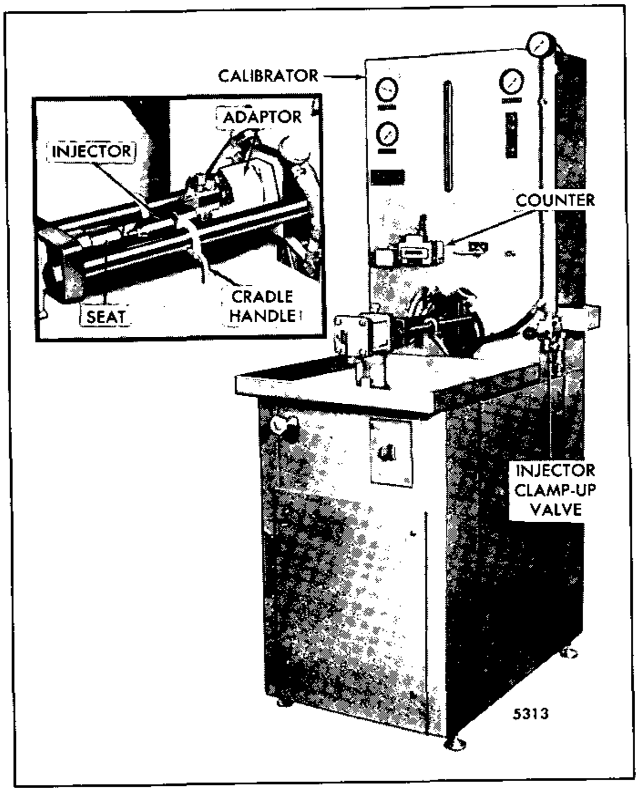


Fig. 7 – Injector in Calibrator J 22410-A

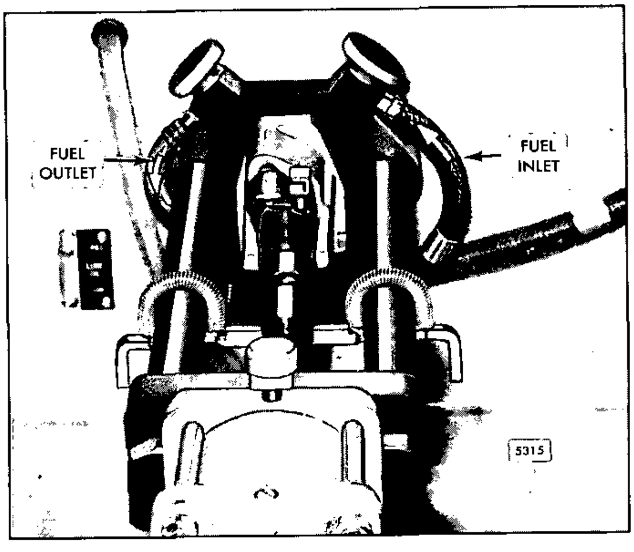


Fig. 8 – Position of Calibrator Fuel Flow Pipes

6. Turn on the main power control circuit (vial light) switch. Then, start the calibrator by turning on the motor starter switch. The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

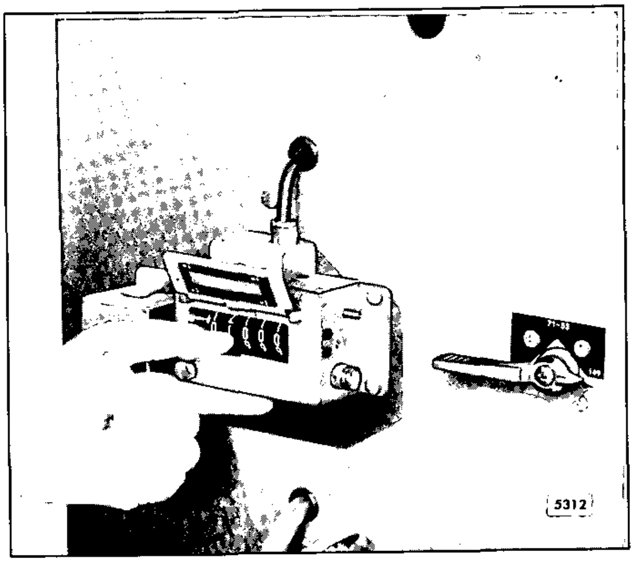


Fig. 9 – Setting Calibrator Stroke Counter

Injector	Calibrator Min.	Calibrator Max.
5A50	53	58
5A55	56	61
5A60	63	68
5A72	70	75
5C50	52	57
5C55	59	64
5C60	66	71
5D45	47	52
5E50	51	56
5E55	58	63
5E60	65	70
C40	42	47
C45	47	52
C50	50	55
M40	40	45
M55	55	60
M60	60	65
N40	42	47
N45	47	52
N50	50	55
6815	55	60
7005	85	91

TABLE 1

7. After the calibrator has started, set the injector rack into the *full-fuel* position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

8. After the air is purged, press the red button on the test switch. This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after the correct number of preset strokes are counted.

9. Shut the calibrator off when two consecutive tests show the same output. Usually, 3 tests are sufficient.

10. Observe the vial readings and refer to Table 1 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to *Troubleshooting Chart 6* for the cause and remedy. See *Injector Calibrator Readings* for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

INJECTOR CALIBRATOR READINGS

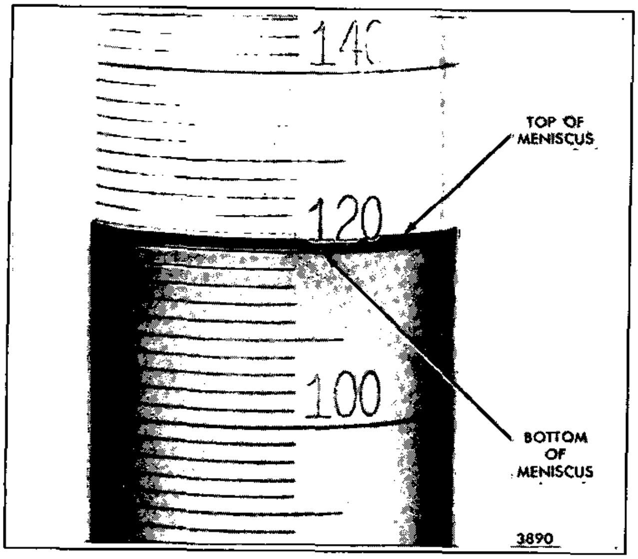


Fig. 10 – Checking Fuel Output

Several factors affect the injector calibrator output readings. The four major items are:

1. **Operator Errors:** If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to (Fig. 10).
2. **Air In Lines:** This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.
3. **Counter Improperly Set:** The counter should be set to divert the injector output at 1,000 strokes, but must be reset for 1,200 strokes to check 35 and 40 cu. mm injectors. It is possible that in returning to the 1,000 stroke setting, an error could be made.

   This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.
4. **Test Oil:** A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

   The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner, if required.

   In addition, other malfunctions such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell–tale conditions. Calibrator accuracy can only be verified using Master Injectors J 26298 or J 35369.

INJECTOR PLUNGERS

The fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in (Fig. 11). The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled. If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

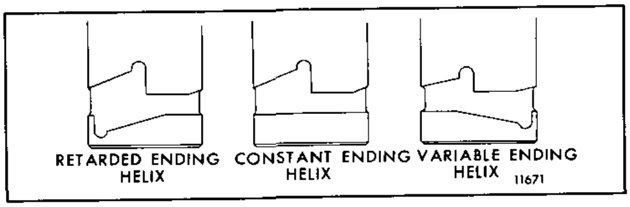


Fig. 11 – Types of Injector Plungers

MASTER INJECTOR CALIBRATING KIT

Use Master Injector Calibrating Kit J 26298 or J 35369 to determine the accuracy of the injector calibrator.

With the test fluid temperature at 100°F ± 1° (38°C ± 1°) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2 percent of the values assigned to the calibrated masters, the calibrator can be considered accurate. Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2 percent variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

PLUNGER/BUSHING AND TIP FLOW GAGE

The injector fuel output is largely dependent upon the combined output of its plunger/bushing and spray tip assemblies. To assist in the rebuilding of fuel injectors that will calibrate within specified limits, it is desirable to preselect and match plunger/bushings and tips according to their output prior to assembly into the injector.

The J 25600–A Plunger/Bushing and Tip Flow Tester, using low pressure air, has the capabilities to measure the output of plunger/bushing and spray tip assemblies. The flow (output) of the spray tip can be correlated to high pressure fuel flow during calibration however, used spray tips because of the worn condition of their spray holes will often flow higher then indicated on a low pressure air tester.

Records should be maintained which indicate the output values of both plunger/bushing and spray tip assemblies being matched with resultent calibration in order to develop a useful matching chart.

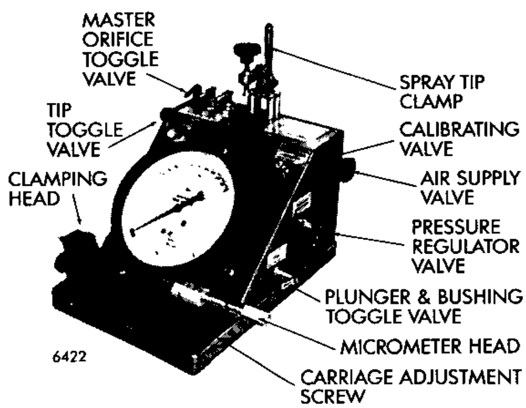


Fig. 12 – Plunger/Bushing and Tip Flow Gage J 25600–A

Installation

Place the flow gage unit in a clean well lighted area that has an air supply of 40 psi (276 kPa), but not more than 150 psi (1034 kPa). Turn off the air supply valve (on the rear of the flow gage) and connect your air line. Familiarize yourself with the various components on the unit (Fig. 12).

Regulated Pressure Adjustment

1. Set all toggle valves in the *closed* position (Fig. 12).
2. Open the calibrating valve approximately 4 turns.

NOTICE: DO NOT use this valve as an air shutoff. Tight closing of this valve may result in valve seat damage.

3. Turn the pressure regulator knob in a counterclockwise direction until it spins freely.
4. Open the air supply valve approximately 3 turns. The pressure regulator is a constant bleed type (.04 cubic feet per minute), the air supply valve is provided as a convenient shutoff to avoid compressed air waste when the flow gage is not in use.

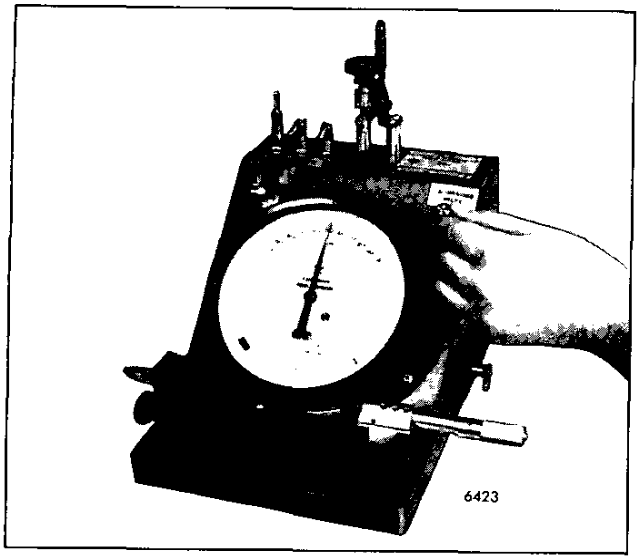


Fig. 13 – Adjusting the Calibrating Valve

5. Adjust the pressure regulator by rotating the knob in a clockwise direction until the gage needle is aligned exactly on the regulated pressure mark.

Calibration to Master Orifice

When no air is leaking through a master orifice, injector tip or plunger/bushing, the gage needle will go to the regulated pressure mark. The master orifices (A, B and C) are provided as controlled air leak passages. Flow tests are conductedfcomparing an injector tip or a plunger/bushing, to an air leak through a master orifice.

1. Be sure all toggle valves are in the *off* position. The gage needle will be at the regulated pressure mark.
2. Open master orifice valve A. The gage needle will move away from the regulated pressure mark.
3. Adjust the calibrating valve, so that the gage needle is exactly at the "set line" (Fig. 13).
4. Close the master orifice toggle valve (needle will return to the regulated pressure mark).
5. You are now ready to perform a flow measurement.

Measuring Spray Tip Flow

1. Clean all spray tips thoroughly (correct flow rate is dependent on a clean spray tip).
2. Observe the number and size of the spray tip holes marked on the narrow end of the spray tip and calibrate to orifice A. Refer to the Chart for the flow values.

TIP STAMP	NOMINAL FLOW VALUE	MASTER ORIFICE CALIBRATION
6-.006	22	
7-.006	69	
8-.0055	26	A
8-.006	48	

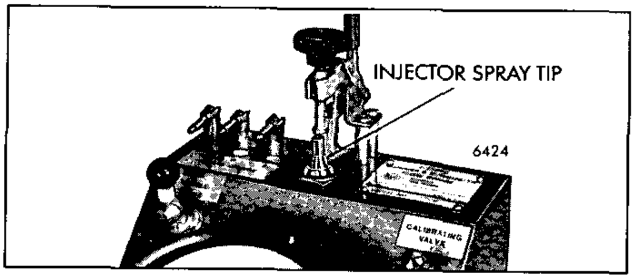


Fig. 14 – Spray Tip Installed in Tester

3. Remove the needle valve, if installed, and clamp the spray tip on the unit (Fig. 14).
4. Open the tip toggle valve and observe the gage reading.
5. The tip can now be compared to the specification sheet and sorted into groups; high, low, mean, etc.

Plunger/Bushing Effective Stroke Measurement

The reason for measuring the flow through the plunger/bushing assemblies is to measure the effective stroke (port closing to opening), in thousandths of an inch. To find the closing and opening points a controlled air leak is used ("A" master orifice is used as reference). When the plunger is moved close to the port *closed* position, the gage needle will be at the set line. At this position, the air leaking out the bushing port matches the air that would leak out the "A" orifice.

As the plunger is moved inward, the leak stops and the gage needle goes to the regulated pressure mark. When the plunger is moved further, air begins to leak again. The gage needle moves away from the regulated pressure mark and moves toward the set line. When the plunger is moved far enough to read the effective stroke, the gage needle will be at the set line again. The distance the plunger has moved as indicated on the micrometer, is the effective stroke. This stroke is measured while the plunger/bushing is held in the *full-fuel* position.

1. Select the proper cradle for the plunger/bushing to be tested and mount on the fixture (Fig. 15).
2. Calibrate to the "A" orifice, see "Calibration to Master Orifice". All plunger/bushing tests use the "A" orifice as reference.

May, 1990

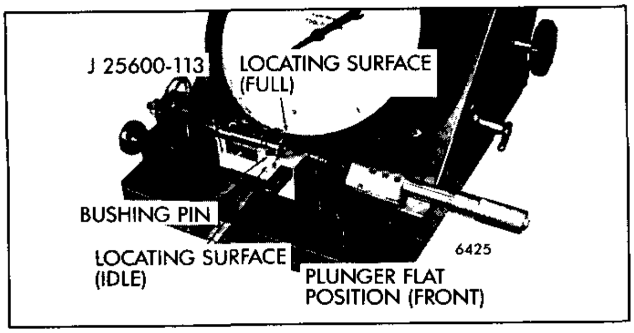


Fig. 15 Cradle Mounted on Fixture

3. Close all toggle valves, gage needle will be at the regulated pressure mark.

4. Adjust the micrometer to zero reading (all zeros).

5. Place the plunger/bushing in the cradle. Be sure the plunger flat and locating pin or slot is properly positioned (Fig. 15). To check in *full–fuel* position, rotate bushing until the bushing pin contacts the rear locating surface.

6. Adjust spring loaded button until enough force is exerted on the plunger flat to hold the plunger steady, but not enough to restrict sliding movement when air pressure is applied.

7. Hold the plunger against the micrometer and rotate the carriage adjustment screw until the plunger almost closes the port (Fig. 16).

8. Open the plunger and bushing toggle valve.

9. If the plunger has not closed the port far enough, an air leak will be heard and the gage needle will be left of the set line. If it has closed the port too far, it will be to the right of the set line, toward or at the regulated pressure mark.

10. Turn the carriage adjustment screw until the gage needle is at approximately 20.

11. Turn the carriage adjustment screw clockwise very slowly until the gage needle is exactly at the set line. Always adjust in this manner, with the needle moving from approximately 20 to the set line.

12. Turn the micrometer thimble clockwise. The gage needle will move toward, and go to the regulated pressure mark. Very little air will be heard leaking.

13. Continue turning clockwise until the gage needle begins to move away from the regulated pressure mark (air from the bushing will again be heard leaking). Turn very slowly until the gage needle reaches the set line.

14. Observe and record the micrometer reading. The number shown is the effective stroke in thousandths of an inch.

15. Turn the micrometer back to zero. Gage needle should return to or very near the set line.

16. Turn off the plunger/bushing test toggle valve.

17. Loosen the clamping knob and remove the plunger/bushing.

18. Only minor carriage adjustment will be required for other plunger/bushing of the same type.

19. Chart the stroke readings and compare to the specifications. Sort into groups, high strokes, low strokes and mean strokes.

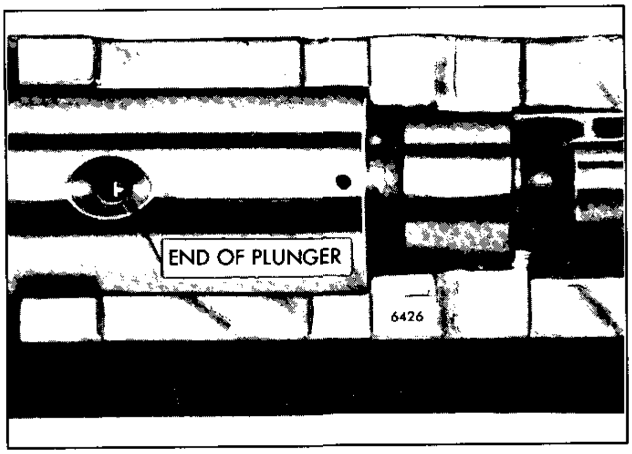


Fig. 16 – End of Plunger Shown in Port

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together (Fig. 17). Alternate the blocks from time to time. For

example, assuming the blocks are numbered 1, 2 and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections.

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark grey. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been finished, remove the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

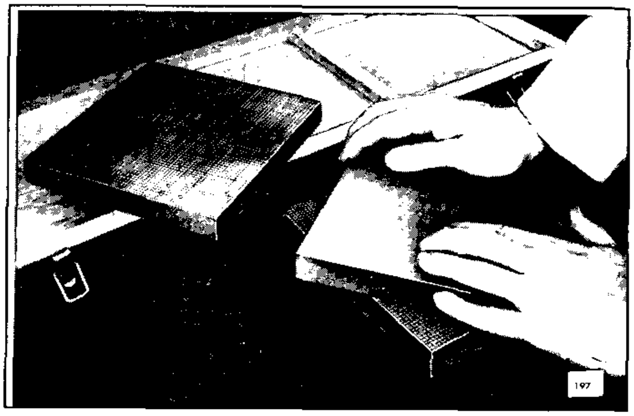


Fig. 17 – Refinishing Lapping Blocks

EFFECT OF PREIGNITION ON FUEL INJECTOR

Preignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders.

When preignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of preignition to avoid recurrence of the problem. Check for oil pull–over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR TIMING

If it is suspected that a fuel injector is "out of time", the injector rack–to–gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (*full–fuel* position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 18) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack–to–gear timing.

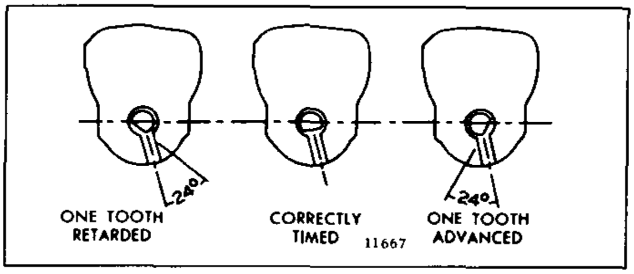


Fig. 18 – Injector Rack–to–Gear Timing

FUEL LINES

Flexible fuel lines are used to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus, flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also, check the filter cover bolts for tightness.

LOCATING AIR LEAKS IN FUEL LINES

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also, check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for fifteen (15) to twenty (20) minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

PRESSURIZE FUEL SYSTEM – CHECK FOR LEAKS

Always, check the fuel system for leaks after injector or fuel pipe replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a serious fuel leak in this area can lead to dilution of the lube oil and bearing and/or cylinder kit damage.

Prime and Purge

Prime and/or purge the engine fuel system before starting the fuel leak check. *Prime* the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (60–80 psi or 413–552 kPa) to the inlet of the secondary filter. If the system is to be *purged* of air as well, allow the fuel to flow freely from the fuel return line until a solid stream without air bubbles is observed.

Check for Leaks

Use one of the following methods to check for leaks.

Method 1. Use when the engine has been operating 20–30 minutes.

After operating the engine, shut it off and remove the rocker covers. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect part (connector washer, connector, injector or jumper line). Test and reinspect.

Method 2. Use when the engine is not operating, such as during or after repairs.

Remove the rocker covers. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method 1. Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gage in the filter adaptor, then apply 60–80 psi (413–552 kPa) fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear. After maintaining 40–80 psi (276–552 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspect connectors. Inspect and repair or replace connectors as necessary. Test and reinspect.

Method 3. Use while the engine is operating at 400–600 rpm.

Apply an outside fuel source capable of 60–80 psi (413–552 kPa) to the outlet side of the secondary filter. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 70 psi (483 kPa). After ten to twenty minutes inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

> **NOTICE:** With the engine at rest, as in Method 2 all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off.

Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exists.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure–holding capability (see Section 2).

Points To Remember

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. The weak or missing puddles show where the leaks are.

All leakage or spillage of fuel during leak detection testing further dilutes the lube oil, so the final step in maintenance of this type should include lube oil and lube oil filter changes.

DETECTING INTERNAL FUEL LEAKS

Used lube oil analysis often identifies a potential source of engine trouble before it occurs. One of the most serious conditions this test can uncover is the presence of excessive fuel in the lubricating oil. Inadequate bearing surface lubrication caused by lube oil dilution is a potential cause of engine malfunction and damage.

While used lube oil analysis can indicate the presence of fuel in engine lubricating oil, other methods must be used to determine its source. Two particularly effective methods involve the use of dye additives.

Red LTO 1140 Dye

The use of Red LTO 1140 dye (a product of Chemserve Corporation, 9505 Copland Ave., Detroit, MI 48209) is effective when bench pressure–testing complete cylinder head assemblies or when pressure testing head assemblies on new or newly overhauled *operating* engines which have *new, clean lubricating oil.* The red dye is most visible when clean lube oil is used. Prepare the dye as follows:

Mix two (2) ounces (59 ml) of Red LTO 1140 dye with five (5) gallons (18.93 liters) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent accidental use and be resealable to prevent contamination when not in use.

Bench Testing

1. To bench test a complete cylinder head assembly, fill a fuel system priming pump (J 5956 or equivalent) with the red dye/fuel mixture.
2. Connect the outlet hose of the priming pump to the fuel inlet manifold. Connect a drain hose from the fuel outlet back to the test fuel container. Make sure that the required restricted fitting is installed in the fuel outlet. This will allow sufficient fluid pressure to build up.
3. Prime the cylinder head fuel system and check for leaks. The test fuel will show up as bright red.
4. Eliminate the cause of any leaks discovered. Wipe off the head components and retest until no further leaks occur.

Running Test

1. To pressure test the cylinder head on a new or newly overhauled engine, isolate the fuel system so that the fuel supply and return lines are connected only to the test container.
2. Start and run the engine on the test fuel at maximum no–load speed for approximately five minutes to bring it to operating temperature. Periodically check the level in the test fuel container to ensure an adequate supply. If necessary, replenish the test fuel by adding one ounce (30 ml) of Red LTO 1140 dye to each 2.5 gallons (9.463 liters) of make–up fuel. Three to five engines can normally be tested before replenishing the fuel.
3. Stop the engine and remove the rocker covers. Check the cylinder head and all fuel connections for any sign of fuel leakage. The test fuel will show up as bright red.
4. If any leaks are discovered, eliminate their cause. Wipe all head surfaces and fuel connections clean, then start the engine and retest.
5. When all leaks have been eliminated, replace the rocker covers, reinstall the original fuel lines and connect the engine to its normal fuel source. It is not necessary to change the fuel filter or strainer. Start and run the engine to purge any air from the system.

J 28431 Fluorescent Dye

The use of J 28431 fluorescent dye and a "black light" (ultraviolet light) is preferable when testing an engine that has been in service and has dark lubricating oil (from engine operation). Use the following procedure:

1. Mix four (4) ounces (11 ml) of fluorescent dy additive J 28431 with four (4) gallons (15.14 liters) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent its accidental usage and be resealable to prevent contamination when not in use.
2. Isolate the engine fuel system so that the supply and return lines are connected only to the test fuel container.
3. Start and run the engine on the test fuel at maximum no–load speed for approximately five minutes to bring

it to operating temperature. Periodically, check the level in the test fuel container to ensure an adequate supply. If necessary, replenish the test fuel by adding one ounce (30 ml) of fluorescent dye for each gallon (3.79 liters) of make–up diesel fuel. Normally, three to five units can be tested before replenishing the fuel.

4. With the engine idling and the rocker covers removed, shine the "black light" over the head assembly. Lube oil will show up as a dull blue. A fuel leak will glow a bright yellow. This type of test is best conducted in a darkened or shadowed area. The darker the area surrounding the unit being tested, the easier it is to see the fluorescent dye.

5. If bright yellow dye is detected, determine the cause of the fuel leak and eliminate it. Wipe the cylinder head and fuel connections clean, start and idle the engine and reckeck the head area.

6. When all leaks have been eliminated, reinstall the original fuel lines and connect the engine to its normal fuel source. It is not necessary to change the fuel filter or strainer. Start and run the engine to purge any air from the fuel system.

Normal Fuel Weepage

Some fuel weepage may normally be encountered from the follower and/or rack on DDC injectors while performing this test. Special consideration must be given to this weepage and the fact that it should not be allowed to exceed the DDC guidlines for pressure holding test (see Section 2.1.1) and the specification for lube oil dilution (2.5%).

Since all leakage or spillage of fuel during leak detection testing dilutes the lube oil, the final step in maintenance of this type should include lube oil and lube oil filter changes.

• FUEL JUMPER LINE MAINTENANCE

Maintenance and service personnel should be aware that severe engine damage could result from fuel oil leakage into the lubricating oil and should therefore, follow proper procedures when removing, handling and installing fuel jumper lines (fuel pipes).

The fuel jumper lines which carry fuel to and form the fuel injectors must be handled and installed very carefully to prevent line damage that can result in severe engine damage. Severe fuel leakage, if not detected, can also result in an over–filled crankcase (oil pan) which can cause an abnormal amount of fuel and lubricating oil vapor to escape from the engine and crankcase breathers. An abnormal concentration of fuel and lube oil vapors is flammable and could ignite in a closed engine compartment.

The following are some of the conditions that can result in fuel jumper line leakage:

1. Improper handling and storage of jumper lines when servicing the engine can result in physical damage and contamination.

2. Careless use of special tool (socket) J 8932–01 during removal or installation can cause a jumper line to bend and be permanently distorted.

3. Reuse of a bent or distorted jumper line can result in excessive stress and cause the line to crack or fracture at or above the flared ends of the jumper line. A fuel leak will ultimately result.

4. Excessive tightening of the jumper line nut will distort and fracture the flared end of the jumper line, resulting in a fuel leak.

NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

To help insure more consistent fastening, tighten fuel pipe nuts on jumper lines to the single torque values shown below. Use fuel line nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds).

NOTICE: Because of their low friction surface, Endurion®–coated nuts on fuel jumper lines must be tightened to 130 ***lb–in*** (14.69 N·m) torque, instead of the 160 ***lb–in*** (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion®–coated nuts on the same cylinder head.

Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

NOTICE: When installing fuel jumper lines, *Do Not Overtighten.* Damage to the jumper line flares and connector seats can result from excessive tightening, causing fuel leakage into the lubricating oil.

O–ring sealed fuel pipes may be reused if not damaged. To avoid fuel leakage, always install new seals when replacing the fuel pipes on an engine. Tighten O–ring sealed fuel pipe nuts to 143 lb–in (16.16 N·m) torque with "clicker" type torque wrench J 24405 (calibrated in inch–lbs).

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)
O–Ring Sealed Pipes	143 lb–in. (16.6 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

Jumper Line Nut Torque Chart

5. Damaged threads and flare seats on the injector and cylinder head jumper line connectors can also result in fuel leakage.

6. Leaks can also occur at injector filter nut gaskets and/or cylinder head connector washers due to distortion, damage or incorrect torque.

The following troubleshooting procedure is recommended after installation of fuel jumper lines and/or connectors to determine if fuel leakage is present.

Checking for Fuel Leaks

Always check the fuel system for leaks after injector or fuel jumper line replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a fuel leak in this area can lead to dilution of the lube oil. Use one of the following methods to check for leaks.

METHOD A

Use when the engine has been operating 20–30 minutes. After operating the engine, shut it off and remove the rocker cover(s). Discard the gasket(s). Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel jumper lines join the fuel line nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect part (connector washer, connector, injector or jumper line). Test and reinspect.

METHOD B

Use when the engine is not operating such as during or after repairs. Remove the rocker cover(s). Discard the gasket(s). Pour clean lube oil over the fuel jumper lines and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method A. Plug the fuel return line at a convenient location (cylinder head or fuel tank, for example). Disconnect the fuel pump supply line at the inlet of the secondary filter. Connect an external source of pressurized fuel (60–80 psi or 414–552 kPa) to the inlet of the secondary filter cover. Install a pressure gage (0–100 psi or 0–689 kPa) at the outlet of the filter cover. Gage installation can be accomplished by installing a "T" fitting between the filter cover and outlet line or by removing the pipe plug at the outlet in the cover. Use of a gage will allow ready reference to the fuel pressure being maintained for this test. Severe leaks are immediately visible and minor leaks take longer to appear. It may be necessary to maintain fuel pressure for a period of 20 to 30 minutes in order to find minor leaks. Leaks may be repaired by replacing damaged parts or determining if the part is loose and below torque specifications. Test and reinspect.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method B. Injectors should be removed from the engine and high pressure tested as outlined in Section 2.1 or 2.1.1.

METHOD C

Use while the engine is operating at 400–600 rpm. Apply an outside fuel source capable of 60–80 psi (414–552 kPa) to the outlet side of the secondary filter. Pour lube oil over the fuel jumper lines and connectors so that oil puddles form where jumper lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 60–80 psi (414–552 kPa). After 10–20 minutes, inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

Slightly worn injector plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exist.

METHOD D

Fluorescent dye fuel leak testing. When testing an engine that has been in service, it will be preferable to use the fluorescent dye and black light method of testing. Proceed as follows:

1. Mix 4 oz. of fluorescent additive J 28431 with 4 gallons (15 liters) of clean diesel fuel (#1 or #2) in a clean container. The container should be marked "Test Fuel" and be resealable so that it won't be contaminated when not being used.
2. Isolate the engine fuel system so that the supply and return fuel lines are connected only to the test fuel container. It will be necessary to intermittently check the fuel level to maintain an adequate supply.
3. Warm up the engine by operating it at maximum no–load speed for approximately 15 minutes.
4. With the engine idling and the rocker cover removed, shine the black light over the head assembly. The lube oil will show a dull blue. If a fuel leak is present, the fuel with the fluorescent dye will glow a bright yellow.
5. After the cause of the fuel leak has been determined and corrected, wipe the area and fuel connections clean and recheck with the black light. When no leaks are present, reassemble the unit withe original fuel lines and normal fuel source. It is not necessary to change the fuel filters. Run the engine to purge the air from the fuel system.

With the engine at rest, all injectors will leak to some extent when pressurized. The leakage occurs because there is no other place for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off. Special consideration must be given to this weepage. If considered to be excessive, the injector should be removed and tested for pressure holding capabilities.

NOTICE: Since all leakage or spillage of fuel during leak detection testing dilutes the lube oil, the final step in maintenance of this type should include lube oil and lube oil filter changes.

Use new gasket(s) and reinstall the valve rocker cover(s).

POINTS TO REMEMBER

1. Lube oil puddle inspection is one method of testing the fuel system for internal leaks. The missing puddles show where the leaks are. This test can be performed any time the rocker covers are removed, after the fuel jumper lines and connectors have been splashed with clean lube oil and there is normal fuel pressure in the system.
2. All leakage or spillage of fuel during leak detection testing further dilutes the lube oil.
3. The final step in maintenance of this type should include lube oil filter changes if a fuel leak is detected.
4. Oil level above the dipstick "full" mark or a decrease in lube oil consumption may indicate internal fuel leaks.
5. Improper storage, handling or installation of jumper lines can cause fuel leakage, resulting in lube oil dilutuion and severe engine damage.

TROUBLESHOOTING

FUEL PUMP

The fuel pump is so constructed as to be inherently trouble free. By using clean, water–free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel supply valve is open. Also, check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine every cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then, lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

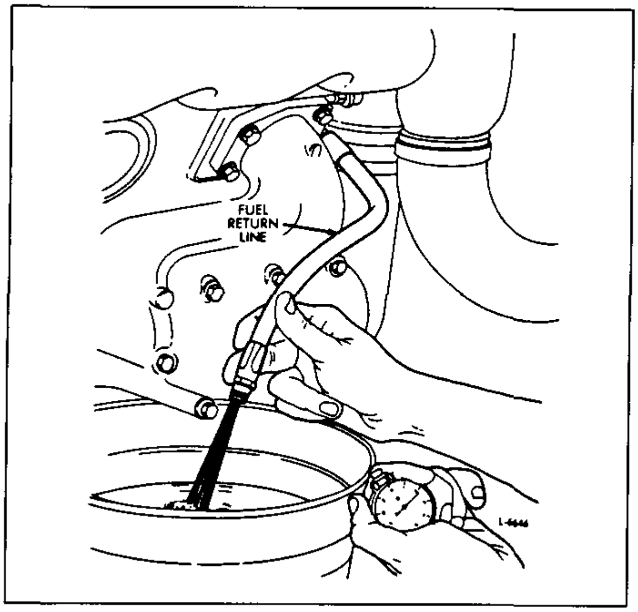


Fig. 24 – Measuring Fuel Flow

1. Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 24).
2. Start and run the engine at 1,200 rpm and measure the fuel flow. Refer to Section 13.2 for the specified quantity per minute.
3. Immerse the end of the fuel hose in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.
4. If the fuel flow is insufficient for satisfactory engine performance, then:
   a. Replace the element in the fuel strainer. Then, start the engine and run it at 1,200 rpm to check the fuel flow. If the flow is still unsatisfactory, perform Step "b" below:
   b. Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in Step "c".
   c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screwdriver. If a cylinder has been misfiring. there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.
2. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.
3. Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

AIR–OPERATED VARIABLE HIGH SPEED GOVERNORS

The most common condition is that the minimum rpm is too high. This is especially true on kit installations to an unknown governor. The most frequent causes are these:

1. Lack of enough air pressure to completely overcome the high–speed spring preload.

Series 53 engines require 90 psi (621 kPa) or more. This air pressure is required at the governor after the regulator. The regulator must have an operating range of 0–120 psi (0–827 kPa).

2. An interaction between the idle circuit and the high speed circuit.

Many Detroit Diesel Corporation governors were designed to idle as low as 350 rpm. If these older design governors are being modified, a low minimum control with the VHS cannot be obtained, especially if a high normal idle is used. All engines supplied by Detroit Diesel Corporation with the VHS feature installed as original equipment have a compatible governor which will allow control from no–load to within 100 rpm of idle.

NOTICE: Minimum certified idle values should not be violated.

Single weight governors capable of accepting the VHS are also capable of reducing the minimum rpm to within 100 rpm of idle.

3. Idle screw protrudes beyond VHS position, or elastic stop nut is not tight.

Determine if the idle screw or piston hits the VHS cover.

If idle screw hits the VHS cover, raise the idle until the screw is flush with the end of the piston. In certain cases the idle screw may have to be shortened to meet the criteria of being flush and acquire the desired idle speed.

If the piston hits first, the elastic stop nut is not properly adjusted. Readjust, making sure that the piston is bottomed, then proceed to adjust the elastic stop nut (See Section 2.7.1.5).

4. Engine overshoot.

This usually relates to the non–synchronized engagement of the throttle lock and the regulated air supply to the VHS housing. A variable orifice (needlevalve type) in one of the air supply lines will provide capability for synchronization as follows:

In cases of *overshoot,* the variable orifice is installed in the supply line to the throttle lock.

In case of *undershoot,* the variable orifice is installed in the regulated air pressure line to the VHS housing.

5. Lowered idle or no load.

Usually caused by air from the air supply leaking into or being trapped in the VHS housing. Any pressure in the VHS housing will lower both the no load and idle. Recheck the air plumbing.

6. Lack of normal power.

The elastic stop nut is screwed in too tight, pulling the high speed plunger off its seat. This will cause low power but no change in the no–load rpm. Readjust the elastic stop–nut.

7. No–load increased.

Interference of the piston and idle screw. Check to be sure that the screw is free as it protrudes through the piston.

CROWN VALVE INJECTORS

Chart 1

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED VALVE SEAT
2. VALVE SEAT CHIPPED AT POINT OF CONTACT
3. CRACKED VALVE SEAT
4. WORN VALVE OR VALVE STOP
5. WORN OR BROKEN VALVE SPRING
6. DIRT OR FOREIGN MATERIAL IN INJECTOR
7. WORN VALVE STOP SEAT IN CAGE

HIGH VALVE OPENING PRESSURE

Probable Cause

8. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
9. CARBON IN SPRAY TIP ORIFICES

SUGGESTED REMEDY

1. A worn or eroded valve seat may be lapped, but not excessively as this would reduce thickness of the part causing a deviation from the valve stack–up dimension.
2. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the I.D. of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve opening pressure.
3. Replace the valve seat.
4. Replace the valve or valve stop.
5. Replace the spring. Check the valve cage and valve stop for wear; replace them; if necessary.
6. Disassemble and clean the injector.
7. Replace the valve cage.
8. Carbon in the tip should be removed with tip reamer J 1243 which is especially designed and ground for this purpose.
9. Check the size of the spray tip orifices. Then, using tool J 4298–1 with the proper size wire, clean the orifices.

CROWN VALVE INJECTORS

Chart 2

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. CRACKED VALVE PARTS
4. VALVE SEAT CHIPPED AT POINT OF CONTACT
5. WORN OR ERODED VALVE SEAT
6. WORN OR BROKEN VALVE SPRING
7. WORN VALVE
8. DEFECTIVE SEAL RING
9. BODY PLUG LEAKS
10. FILTER GASKETS LEAK
11. POOR SEALING SURFACES ON FUEL FITTINGS
12. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

1. Lap the injector body.
2. Tighten the nut to 55–65 lb–ft (75–88 N·m) torque. Do not exceed the specified torque.
3. Replace the valve parts.
4. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the I.D. of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve opening pressure.
5. A worn or eroded valve seat may be lapped, but not excessively as this would reduce the thickness of the part causing a deviation from the valve stack–up dimension.
6. Replace the spring. Check the valve cage and valve stop for wear; replace them, if necessary.
7. Replace the valve.
8. Replace the seal ring.
9. Install new body plugs.
10. Replace the filter gaskets and tighten the filter caps to 65–75 lb–ft (88–102 N·m) torque.
11. Clean up the sealing surfaces or replace the filter caps, if necessary.
12. Disassemble the injector and clean all of the parts.

CROWN VALVE INJECTORS

Chart 3

INCORRECT INJECTOR OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. CARBON BUILD–UP IN SPRAY TIP
4. WORN PLUNGER AND BUSHING
5. CRACKED VALVE PARTS
6. CRACKED BUSHING
7. IMPROPERLY LAPPED SURFACES
8. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
9. RACK AND GEAR NOT IN TIME

SUGGESTED REMEDY

1. Clean the orifices with tool J 4298–1, using the proper size wire.
2. Replace the spray tip.
3. Clean the injector tip with tool J 1243.
4. After the possibility of an incorrect or faulty tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

   NOTICE: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the *Fuel Output Check Chart,* try changing the spray tip. However, use only a tip specified for the injector being tested.
5. Replace the cracked parts.
6. Replace the plunger and bushing assembly.
7. Lap the sealing surfaces.
8. Disassemble the injector and clean all of the parts.
9. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.

NEEDLE VALVE INJECTORS

Chart 4

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN SPRAY TIP
2. WORN OR DAMAGED NEEDLE VALVE QUILL
3. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
4. WORN OR BROKEN VALVE SPRING
5. DIRT OR FOREIGN MATERIAL IN INJECTOR

HIGH VALVE OPENING PRESSURE

Probable Cause

6. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
7. CARBON IN SPRAY TIP ORIFICES

SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.
2. Replace the needle valve and spray tip assembly.
3. Replace the spring seat.
4. Replace the valve spring.
5. Disassemble the injector and clean all of the parts.
6. Remove the carbon in the spray tip with tip reamer J 9464–01 which is especially designed and ground for this purpose.
7. Check the size of the spray tip orifices. Then, using tool J 4298–1 with the proper size wire, clean the orifices.

NEEDLE VALVE INJECTORS

Chart 5

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. EXCESSIVE PLUNGER TO BUSHING CLEARANCE
4. CRACKED SPRAY TIP
5. WORN OR ERODED NEEDLE VALVE
6. WORN OR ERODED NEEDLE VALVE SEAT IN SPRAY TIP
7. WORN OR BROKEN NEEDLE VALVE QUILL
8. WORN OR BROKEN VALVE SPRING
9. WORN OR DAMAGED VALVE SPRING SEAT
10. DEFECTIVE SEAL RINGS
11. BODY PLUG LEAKS
12. FILTER GASKETS LEAK
13. POOR SEALING SURFACES ON FUEL FITTINGS
14. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

1. Lap the injector body.
2. Tighten the injector nut to 75–85 lb-ft (102–115 N·m) torque. Do not exceed the specified torque.
3. Replace the plunger and bushing.
4, 5, 6 and 7. Replace the needle valve and spray tip assembly.
8. Replace the valve spring.
9. Replace the valve spring seat.
10. Replace the seal rings.
11. Install new body plugs.
12. Replace the filter cap gaskets and tighten the filter caps to 65–75 lb-ft (88–102 N·m) torque.
13. Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.
14. Disassemble the injector and clean all of the parts.

NEEDLE VALVE INJECTORS

Chart 6

INCORRECT INJECTOR OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. CARBON BUILD–UP IN SPRAY TIP
4. WORN PLUNGER AND BUSHING
5. WORN OR DAMAGED NEEDLE VALVE QUILL
6. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
7. WORN OR BROKEN VALVE SPRING
8. CRACKED CHECK VALVE GAGE, SPRING CAGE OR SPRAY TIP
9. CRACKED BUSHING
10. IMPROPERLY LAPPED SURFACES
11. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
12. RACK AND GEAR NOT IN TIME
13. SPRAY TIP–PLUNGER AND BUSHING COMBINATION PROVIDES INCORRECT OUTPUT

SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts.*
2. Replace the needle valve and spray tip assembly.
3. Clean the spray tip with tool J 1243.
4. After the possibility of an incorrect or faulty spray tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

   NOTICE: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the *Fuel Output Check Chart,* try changing the spray tip. However, use only a tip specified for the injector being tested.

5. Replace the needle valve and spray tip assembly.
6. Replace the spring seat.
7. Replace the valve spring.
8. Replace the cracked parts.
9. Replace the plunger and bushing assembly.
10. Lap the sealing surfaces.
11. Disassemble the injector and clean all of the parts.
12. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth on the rack.
13. Replace the spray tip and the plunger and bushing assembly to provide the correct output.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	260M BOLTS TORQUE N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	280M OR BETTER TORQUE N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N·m)
Governor Control Housing to Flywheel Housing	5/16–18	10–12		14–16
Blower Drive Assembly to Flywheel Housing	3/8–16	20–25		27–34
Injector Clamp Bolt	3/8–16	20–25		27–34
Rocker Arm Bracket Bolts	7/16–14	50–55		68–75
Governor Drive Gear Retaining Nut (In–line engine)	5/8–18	125–135		170–183
•Fitting, Fuel Pump Inlet/Outlet	1/4–	14–16		19–22
•Fitting, Fuel Pump Inlet/Outlet	3/8–	18–22		24–30
•Fitting, Fuel Pump Inlet/Outlet	1/2–	20–25		27–34
Connector, Cyl. Head Fuel (Flared End Fuel Pipe)	3/8–24	20–28		27–28
•Connector, Cyl. Head Fuel (0–ring sealed fuel pipe)	3/8–24	37		50
•Fuel pipe nut (Endurion® coated)	3/8–24		130 lb–in	14.69
•Fuel pipe nut (uncoated)	3/8–24		160 lb–in	18.3
•Fuel pipe nut (load limiting device)	3/8–24		160 lb–in	18.3
•Fuel pipe nut (Jacobs Brake)	3/8–24		120 lb–in	13.6
•Fuel pipe nut (0–ring sealed fuel pipe)	1/2–20		143 lb–in	16.16
•Injector Filter Caps				
Non–blued cap on non–blued body	5/8–24	62		84
Blued cap on blued body	5/8–24	70		95
Non–blued cap on blued body or blued cap on non–blued body	5/8–24	62		84
•Injector Filter Cap (0–ring sealed fuel pipe)	1/2–20	70		95
•Injector Nut (crown valve)	15/16–24	55–65		75–88
•Injector Nut (needle valve)				
Non–blued nut on non–blued body	15/16–24	50		68
Blued nut on blued body	15/16–24	80		108
Non–blued nut on blued body or blued nut on non–blued body	15/16–24	65		88

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Auxiliary injector tester (N injectors)	J 22640–A
• Field modification kit (converts 22640 tester to 22640–A tester)	J 22640–51
Fuel pipe socket	J 8932–01
Fuel system primer	J 5956
Injector body reamer	J 21089
Injector body thread reconditioning set	J 22690
Injector calibrator	J 22410–A
Injector nut seal ring installer	J 29197
Injector service set (includes *tools)	J 1241–07
Injector service set (N injectors – includes #tools)	J 23435–02
*Deburring tool	J 7174
#*Fuel hole brush	J 8152
#*Injector nut socket wrench	J 4983–01
#*Injector nut and seat carbon remover set	J 9418
#*Injector spray tip driver	J 1291–02
*Injector tip cleaner	J 1243–01
#*Pin vise	J 4298–1
#*Rack hole brush	J 8150
#*Spray tip carbon remover	J 9464–01
#*Spray tip seat remover	J 4986–01
*Spray tip wire (.005")	J 21459–01
#*Spray tip wire (.0055")	J 21460–01
#*Spray tip wire (.006")	J 21461–01
#*Wire sharpening stone	J 8170
Injector test oil (Available in 5, 15, 30 and 55 gallons)	J 26400
Injector tester	J 9787
Injector tester	J 23010–A
Injector tester modification package (J 23010–A only)	J 23010–194
Injector tip concentricity gage	J 5119
Injector vise and rack freeness tester	J 22396
Injector vise jaws (offset body)	J 8912
Injector vise jaws (standard body)	J 1261
Lapping block set	J 22090–A
• Master injector calibrating kit	J 35369
Polishing compound (N injectors)	J 23038
Polishing stick set (N injectors)	J 22964
Spray tip flow gage	J 25600–A
Spray tip gage (N injectors)	J 9462–02
Spring tester	J 22738–02
Wire brush (brass)	J 7944
INJECTOR TUBE	
Injector tube service tool set	J 22525–A
Injector tube service tool set (for power equipment)	J 22515–A

TOOL NAME	TOOL NO.
FUEL PUMP	
Fuel pump primer	J 5956
Fuel pump tool kit	J 34607
Fuel pump tool set	J 1508–D
Fuel pump wrench	J 4242
MECHANICAL GOVERNOR	
Adjustable spanner wrench	J 5345
Control link operating lever bearing remover/installer	J 8985
Governor cover bearing installer	J 21068
Governor cover bearing remover/installer	J 21967–01
Governor weight spacer (6V–53 engine)	J 8984
Spring retainer nut wrench	J 5895
Variable speed spring housing bearing installer set	J 9196

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

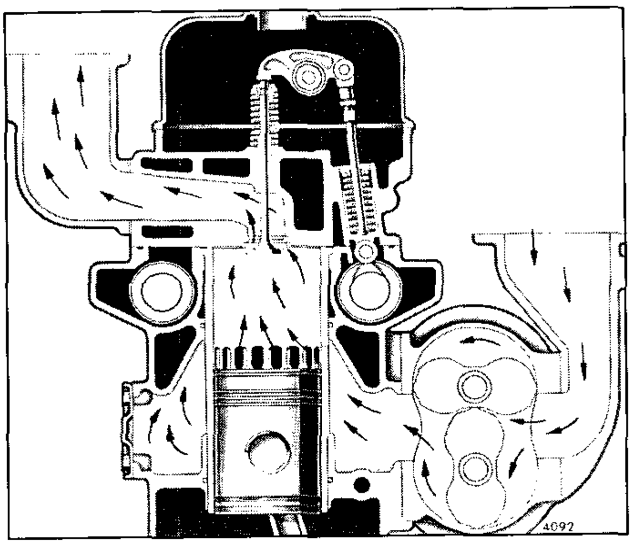


Fig. 1 - Air Flow Through Blower and Engine (In-Line Engine)

In the scavenging process employed in the Series 53 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Figs. 1 and 2. The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

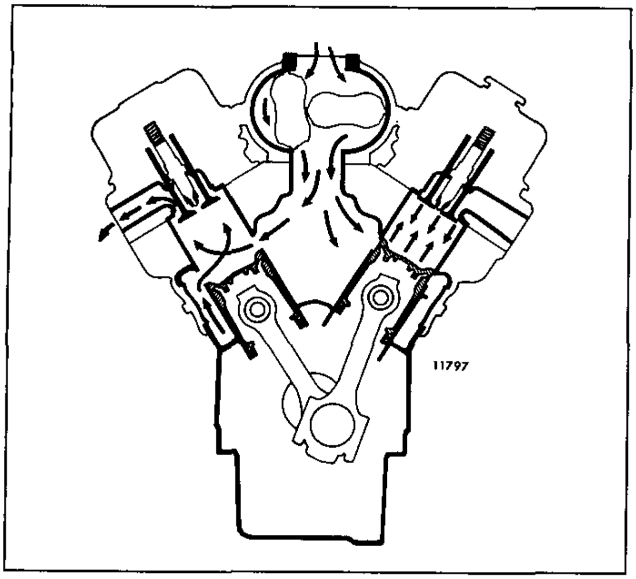


Fig. 2 – Air Flow Through Blower and Engine (V–Type Engine)

AIR CLEANER

The air cleaner is designed to remove foreign matter from the air, pass the required volume of air for proper combustion and scavenging and maintain their efficiency for a reasonable period of time before requiring service.

The importance of keeping dust and grit–ladden air out of an engine cannot be over–emphasized since clean air is so essential to satisfactory engine operation and long engine life. The air cleaner must be able to remove fine materials such as dust and blown sand as well as coarse materials such as chaff, sawdust, or lint from the air. It must also have a reservoir capacity large enough to retain the material separated from the air to permit operation for a reasonable period before cleaning and servicing are required.

Dust and dirt entering an engine will cause rapid wear of piston rings, cylinder liners, pistons and the exhaust valve mechanism with a resultant loss of power and high lubricating oil consumption. Also, dust and dirt which is allowed to build–up in the air cleaner passages will eventually restrict the air supply to the engine and result in heavy carbon deposits on pistons and valves due to incomplete combustion.

Air Cleaner Mounting

Air cleaner mountings vary in accordance with the air cleaner installation and the engine units on which they are employed. The light duty oil wetted type, oil bath type and the dry type air cleaners are mounted on the air inlet housing. Heavy duty air cleaners are remotely mounted from the air inlet housing and are connected to it by air tight ducts.

Current design heavy duty air cleaners may be mounted in parallel to the same air inlet elbow for additional air cleaner capacity. Some earlier installations introduced an additional cleaner into the system between the main cleaner and the blower inlet. The heaviest cleaning job was imposed upon the main cleaner, whereas the additional cleaner, called the after cleaner, filters out any dirt particles that may have passed through the main cleaner.

Air Cleaner Maintenance

Although the air cleaner is highly efficient, this efficiency depends upon proper maintenance and periodic servicing.

Damaged gaskets, loose hose connections or leaks in the duct work, which permit dust–laden air to completely bypass the cleaner and enter the engine directly, will lower the efficiency of the air cleaner. If the air cleaner is not serviced periodically, the engine will not receive a sufficient amount of clean air.

No set rule for servicing an air cleaner can be given since it depends upon the type of air cleaner, the condition of the air supply and the type of application. An air cleaner operating in severe dust will require more frequent service than an air cleaner operating in comparatively clean air. The most satisfactory service period should be determined by frequently inspecting the air cleaner under normal operating conditions, then setting the service period to best suit the requirements of the particular engine application.

The following maintenance procedure will assure efficient air cleaner operation.

1. Keep the air cleaner tight on the air intake pipe to the engine.

2. Keep the air cleaner properly assembled so the joints are strictly oil and air tight.

3. Repair any damage to the air cleaner or related parts immediately.

4. Inspect and clean or replace the air cleaner element as operating conditions warrant. In the dry type cleaner, it is possible to clean and reuse the element several times as long as the paper is not ruptured in the process. In an oil bath type cleaner keep the oil at the level indicated on the air cleaner sump. Overfilling may result in oil being drawn through the element and into the engine, thus carrying dirt into the cylinders and also resulting in excessive engine speed.

5. After servicing the air cleaner, remove the air inlet housing and clean accumulated dirt deposits from the blower screen and the inlet housing. Keep all air intake passages and the air box clean.

6. Where a rubber hose is employed, cement it in place. Use a new hose and hose clamps, if necessary, to obtain an air tight connection.

7. Carefully inspect the entire air system periodically. Enough dust–laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.

OIL BATH TYPE AIR CLEANER

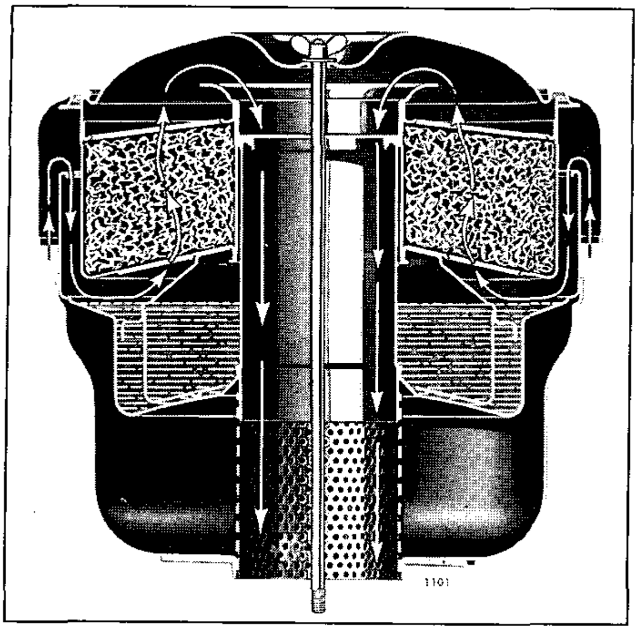


Fig. 1 – Light Duty Oil Bath Type Air Cleaner

Light Duty Oil Bath Type Air Cleaner

The light duty oil bath type air cleaner consists essentially of a wire screen element supported inside a sylindrical housing which contains an oil bath directly below the element (Fig. 1). Air drawn through the cleaner passes over the top of the oil bath. The air stream direction reverses when the air impinges on the oil in the sump and is then directed upwards by baffles. During this change in the direction of air flow, much of the foreign matter is trapped by the oil and is carried to the sump where it settles out. The air passes upward through the metal–wool elements where more dust and the entrained oil are removed. A second change of air direction, at the top of the cleaner directs the air downward through the center tube and into the blower inlet housing.

Service (Light–Duty)

To service the light duty air cleaner, loosen the wing bolt and remove the cleaner from the air inlet housing. The cleaner may then be separated into two sections. The upper section contains the metal–wool elements and the lower section is made up of the oil sump, removable baffle and the center tube.

The upper shell and metal–wool elements may be cleaned by soaking the entire section in kerosene or fuel oil. This will loosen the oil and dust in the elements and facilitate flushing out the dirt. The oil should be emptied from the sump, the baffle removed, and the sump and baffle cleaned in kerosene or fuel oil to remove all sediment. A lintless cloth should be pushed through the center tube of the cleaner before the baffle is installed and the sump refilled to the oil level mark with clean engine oil. NEVER use cotton waste to wipe the center tube. Use the same viscosity and grade of oil that is used in the engine crankcase. All gaskets and sealing surfaces should be checked and cleaned to ensure air–tight seals.

After the filter element has been thoroughly drained of the flushing fluid, the cleaner should be assembled. However, before installing the cleaner on the engine, the air inlet housing and blower inlet screen should be checked for the presence of dirt accumulations. If the service period has been too long, or dust–laden air has been leaking past the seals, the inlet housing and screen will be dirty. This will serve as a good check on the maintenance of the air cleaner installation. When installing the cleaner (and its seal) on the inlet housing, be sure that the cleaner seats properly, then tighten the wing bolt securely until the cleaner is rigidly mounted.

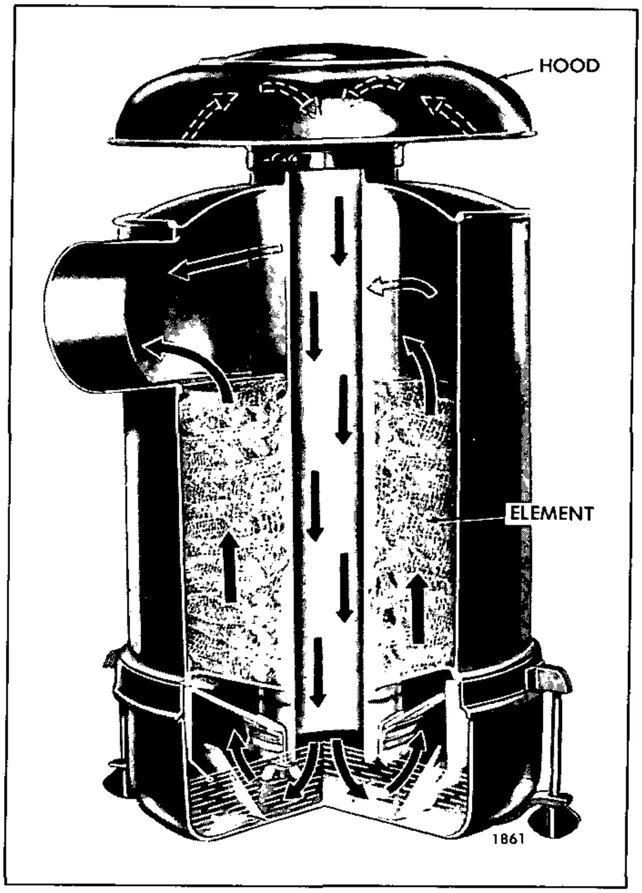


Fig. 2 – Heavy Duty Oil Bath Type Air Cleaner

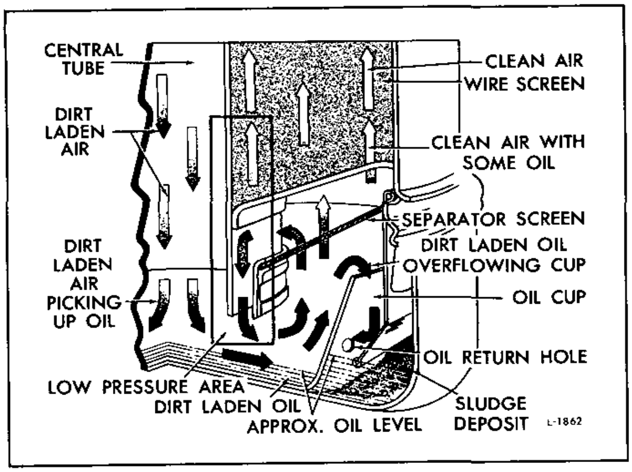


Fig. 3 – Air Flow Through Heavy Duty Oil Bath Air Cleaner

Heavy Duty Type Air Cleaner

In all heavy duty air cleaners air is drawn through the air inlet hood, which acts as a cleaner and down through the center tube (Fig. 2). At the bottom of the tube, the direction of air flow is reversed and oil is picked up from the oil reservoir cup. The oil laden air is carried up into the separator screen where the oil which contains the dirt particles is separated from the air by collecting on the separator screen.

A low pressure area is created toward the center of the air cleaner as the air passes a cylindrical opening formed by the outer perimeter of the central tube and the inner diameter of the separator screen (Fig. 3). This low pressure is caused by the difference in air current velocity across the opening. The low pressure area, plus the effect of gravity and the inverted cone shape of the separator screen, causes the oil and dirt mixture to drain to the center of the cleaner cup. This oil is again picked up by the incoming air causing a looping cycle of the oil, however, as the oil is carried toward another cycle, some of the oil will overflow the edge of the cup carrying the dirt with it. The dirt will be deposited in the outer area surrounding the cup. Oil will then flow back into the cup through a small hole located in the side of the cup. Above the separator screen, the cleaner is filled with a wire screen element which will remove any oil which passes through the separator screen. This oil will also drain to the center and back into the pan. The clean air then leaves the cleaner through a tube at the side and enters the blower through the air inlet housing.

An air inlet hood or pre–screener must be used with the heavy duty air cleaners, depending upon operating conditions. This equipment normally requires cleaning more frequently than the main air cleaner. The usual installation employs an air inlet hood which serves only to prevent rain, rags, paper, leaves, etc., from entering the air cleaner. The smaller cleaners employ a spherical–shaped hood. Air enters the hood through a heavy screen which forms the lower portion of the hood, and the air is reversed in the hood and pulled downward into the air cleaner. The hood is mounted on the air cleaner inlet tube and is held in place by the fit of the hood in the inlet tube.

The larger cleaners use a dome–shaped hood. A heavy screen inside the dome guards against large pieces of foreign material entering the cleaner. The hood is mounted on the air inlet tube of the cleaner and is secured to it by a screw–clamp. As previously mentioned, the hoods serve only to prevent rain and large pieces of foreign material from entering the cleaner. The openings in the hoods should be kept clear to prevent excessive restriction to air flow.

A pre–screener should be used on the inlet tube of the air cleaner instead of the inlet hood for those operations in which the air cleaner elements load up with lint or chaff. The purpose of the pre–screener is to remove as much of the lint or chaff as possible before the air enters the cleaner.

Service (Heavy–Duty)

The air inlet hoods used on heavy–duty air cleaners are not intended to do any cleaning. However, some dirt will collect on the heavy screens and in the hood itself. Therefore, it will be necessary to remove the hood occasionally for cleaning by brushing or with compressed air.

Some applications may be equipped with a pre–screener. The pre–screener catches the lint and chaff on the screen surrounding the shell. This screen can be removed by unhooking the retaining springs, and cleaned by brushing or with compressed air. The shell can be cleaned, if necessary, by wiping it with a lintless cloth. The pre–screener may then be assembled and installed on the cleaner inlet tube.

Although the pre–screener will remove most of the lint and chaff from the air, some may still find its way into the main cleaner. Therefore, it is essential that the fixed element of the main cleaner be checked, each time the cleaner is serviced, to prevent excessive lint deposits.

When the oil sump is removed on some heavy–duty air cleaners, a tray type screen attached to the tube will be visible. It may be removed by loosening the wing nuts and rotating the tray so that it unlocks from the tube. On other heavy duty models, the tray rests on the lip of the inner oil cup of the sump and is not retained by wing nuts.

The efficiency of the tray type oil bath air cleaner can be greatly reduced unless the fibrous material caught in the tray is removed. It is extremely important that the tray be cleaned regularly and properly.

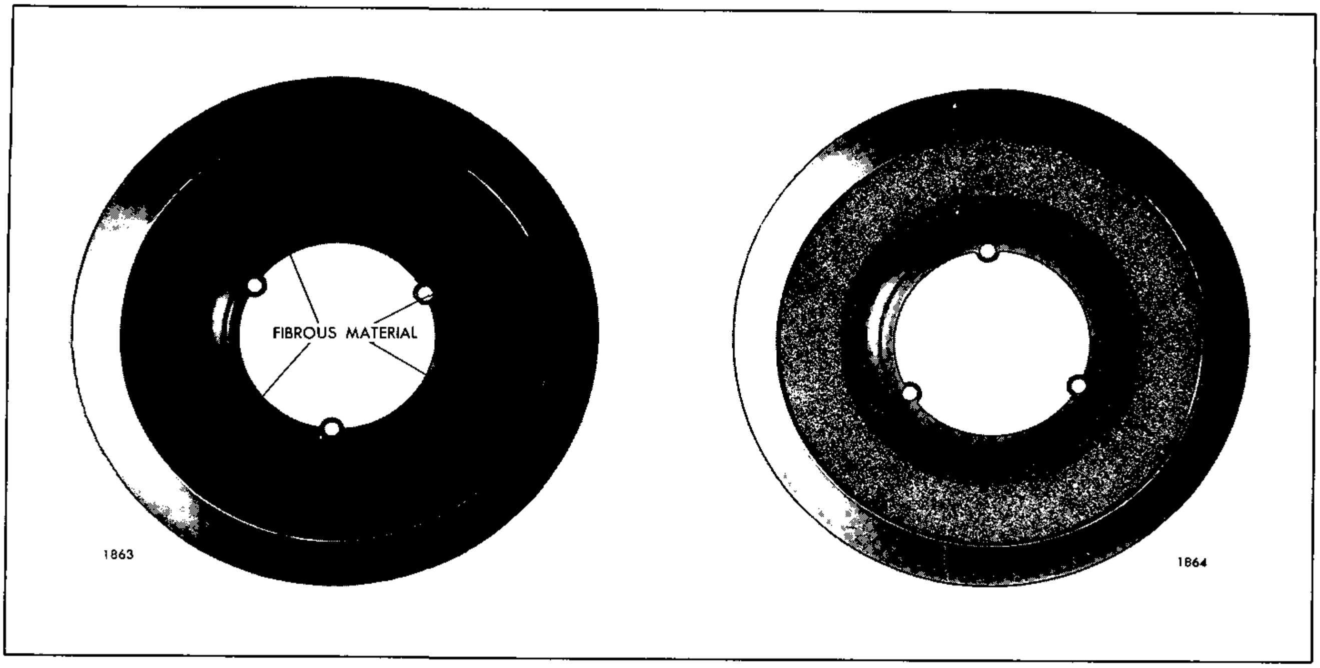


Fig. 4 – Comparison of Air Cleaner Trays

If a tray is plugged with lint or dirt, wash the tray in a solvent or similar washing solution and blow out with high velocity compressed air or steam (Fig. 4). An even pattern of light should be visible through the screens when a clean tray is held up to the light (Fig. 4). It may be necessary, as a last resort, to burn off the lint. Extreme care must be taken not to melt the galvanized coating in the tray screens. Some trays have equally spaced holes in the retaining baffle. Check to make sure that they are clean and open.

It is advisable to have a spare tray on hand to replace the tray that required cleaning. Having an extra tray available makes for better servicing and the plugged tray can be cleaned thoroughly at leisure.

Check for dirt accumulation in air cleaner center tube. Remove dirt by passing a lintless cloth through the center tube. Some tubes have a restricted portion at the lower end and care must be exercised not to damage this end.

Check oil sump for any dirt accumulation in both the inner and outer cups and clean if necessary.

At some regular period of engine service, remove the entire air cleaner from the engine and clean the fixed element. This can be done by passing a large quantity of clean solvent through the air outlet and down into the fixed element. When clean, allow element to dry thoroughly before installing cleaner.

When all of the components have been cleaned, the cleaner is ready for assembly. The removable screen should be installed and the oil sump should be filled with clean engine oil to the indicated level and installed on the cleaner. Care should be exercised that all gaskets and joints are tight. All connections from the cleaner to the engine should be checked for air leaks to prevent any air bypassing the air cleaners.

If it is found that unfiltered air is being admitted into the engine through the duct work of an air cleaner installation, the following procedure may be used for finding air leaks in an air duct system. The air cleaning system does not have to be dismantled, thus effecting a saving in time.

To make this check, it is necessary that suitable plugs be provided to block the air cleaner system inlet and outlet. The air cleaner inlet plug should contain a suitable air connection and shutoff valve to maintain two pounds pressure in the air duct system. The outlet plug need only be of sufficient size to form a completely air–tight seal at the outlet end of the system. Then check the system as follows:

1. Remove the air inlet hood or pre–screener.
2. Insert the plug (with the fitting for the air hose) in the air cleaner inlet to form an air–tight seal.
3. Insert the other plug in the outlet end of the system to form an air–tight seal.
4. Attach an air hose to the plug in the air cleaner inlet and regulate pressure not to exceed 2 psi (14 kPa).
5. Brush a soapsuds solution on all air duct connections. Any opening which would allow dust to enter the

engine can then be detected by the escaping air causing bubbles in the soapsuds solution. All leaks thus discovered should be remedied until the system checks "air–tight".

6. Remove plugs and install air inlet hood or pre–screener.

A rotational type of service program may be followed on heavy duty air cleaner installations that employ a main and after cleaner, in accordance with the following procedure, since the heaviest cleaning job is imposed upon the main cleaner.

1. Remove and clean the sump and removable screen of the main cleaner.
2. Check all joints and tubes of the main cleaner and ensure that they are air–tight.
3. Install the cleaned removable screen on the main cleaner.
4. Remove the sump of the after cleaner and install it on the main cleaner.
5. Remove and clean the removable screen of the after cleaner.
6. Check all joints and tubes of the after cleaner and ensure that they are air–tight.
7. Install the remaining screen and sump on the after cleaner.

The design and function of the heavy duty air cleaners is such that the fixed elements tend to be self–cleaning. However, it may be necessary, occasionally, to remove the entire cleaner from its mountings and clean these elements. If the fixed elements require too frequent cleaning, it is advisable to relocate the air intake to provide a cleaner air supply.

Proper selection of air cleaners and good air cleaner maintenance go "hand–in–hand" in providing long engine life and trouble–free operations.

DRY TYPE AIR CLEANER

UNITED SPECIALTIES AIR CLEANER

The dry type United Specialties air cleaner shown in Fig. 5 consists of a body, dust unloader and element clamped to a base.

Air is drawn through the cleaner intake pipe and is automatically set into a circular motion. This positive spinning of the dirty air "throws out" the heavier particles of dust and dirt where they are collected in the dust port and then expelled through the dust unloader. The circular action continues even during low air intake at engine idle speed.

Service

Service the dry type United Specialties air cleaner as follows:

1. Loosen the clamp screw and check the dust unloader for obstruction or damage. Refer to Section 15.1 for maintenance.
2. Unlock the spring clamps that hold the cleaner body to the cleaner base which is bolted to the air inlet housing. Remove the body and then remove the element from the cleaner base.
3. Clean the paper pleated air cleaner element as follows:
   a. For a temporary expedient in the field, tap the side or end of the element carefully against the palm of your hand.

   NOTICE: Do not tap the element against a hard surface. This could damage the element.

   b. Compressed air can be used when the major contaminant is dust.

   - **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

   The compressed air should be blown through the element in a direction opposite to the normal air flow. Insert the nozzle inside of the element and gently tap and blow out the dust with air. When cleaning the dust from the outside of the element, hold the nozzle at least 6" from the element.

   c. If allowed, further cleaning (washing, drying, inspection) must be done per the recommendations of the filter element manufacturer.

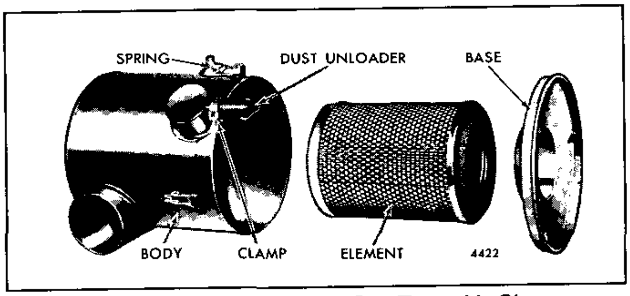


Fig. 5 – United Specialties Dry Type Air Cleaner

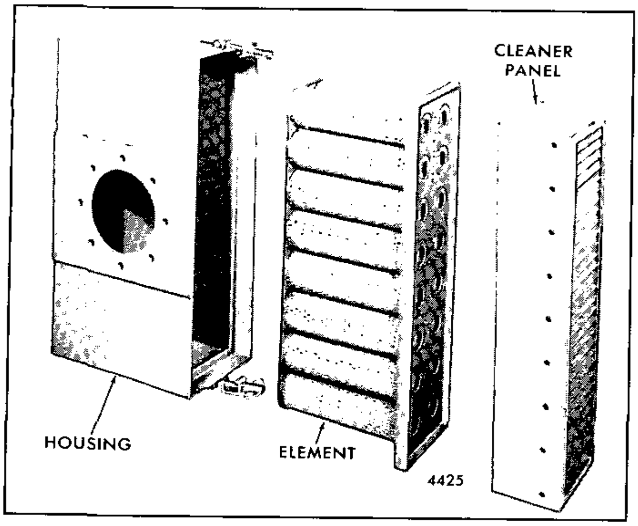


Fig. 6 – Farr Dry Type Air Cleaner

4. Inspect the cleaned element with a light bulb after each cleaning for damage or rupture. The slightest break in the element will admit sufficient airborne dirt to cause rapid failure of piston rings. Replace the element if damaged.

5. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

6. Install the element on the base with the gasket side of the element down against the base. Place the body over the element and the base and tighten the spring clamps by hand.

   Replace the element per the manufacturer's recommendations (normally after 1 year of service), or any time damage is noted.

7. Install the dust unloader and tighten the clamp.

FARR AIR CLEANER

The Farr dry type air cleaner illustrated in Fig. 6 is designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed. The cleaner assembly consists of a cleaner panel with a replaceable impregnated paper filter element.

The cleaner panel and replaceable filter element are held together in a steel housing with fasteners.

Operation

The deflector vanes impart a swirling motion to the air entering the air cleaner and centrifuge the dust particles against the walls of the tubes. The dust particles are then carried to the dust bin at the bottom of the cleaner by approximately 10% bleed–off air and are finally discharged into the atmosphere.

The cleaner panel is fully effective at either high or low velocities.

The remainder of the air in the cleaner reverses direction and spirals back along the discharge tubes again centrifuging the air. The filtered air then reverses direction again and enters the replaceable filter element through the center portion of the discharge tubes. The air is filtered once more as it passes through the pleats of the impregnated paper element before leaving the outlet port of the cleaner housing.

Service

The cleaner panel tends to be self–cleaning. However, it should be inspected and any accumulated foreign material removed during the periodic replacement of the impregnated paper filter element. Overloading of the paper element will not cause dirt particles to bypass the filter and enter the engine, but will result in starving the engine for air.

Replace the filter element as follows:

1. Loosen the wing nuts on the fasteners and swing the retaining bolts away from the cleaner panel.
2. Lift the cleaner panel away from the housing and inspect it. Clean out any accumulated foreign material.
3. Withdraw the paper filter element and discard it.
4. Install a new filter element.
5. Install the cleaner panel and secure it in place with the fasteners.

DONALDSON AIR CLEANER

The Donaldson dry type air cleaners shown in Figs. 7, 8 and 9 are designed to provide highly efficient air filtration under all operating conditions. The cleaners have a replaceable impregnated paper filter element that can be cleaned.

The fins on the element give high speed rotation to the intake air, which separates a large portion of the dust from the air by centrifugal action. The plastic fins, the element and the gasket make up a single replaceable element assembly.

The dust is swept through a space in the side of the baffle and collects in the lower portion of the body or dust cup. The dust remaining in the precleaned air is removed by the element.

The dry type cleaner *cannot be used* where the atmosphere contains oil vapors, or fumes from the breather can be picked up by the air cleaner.

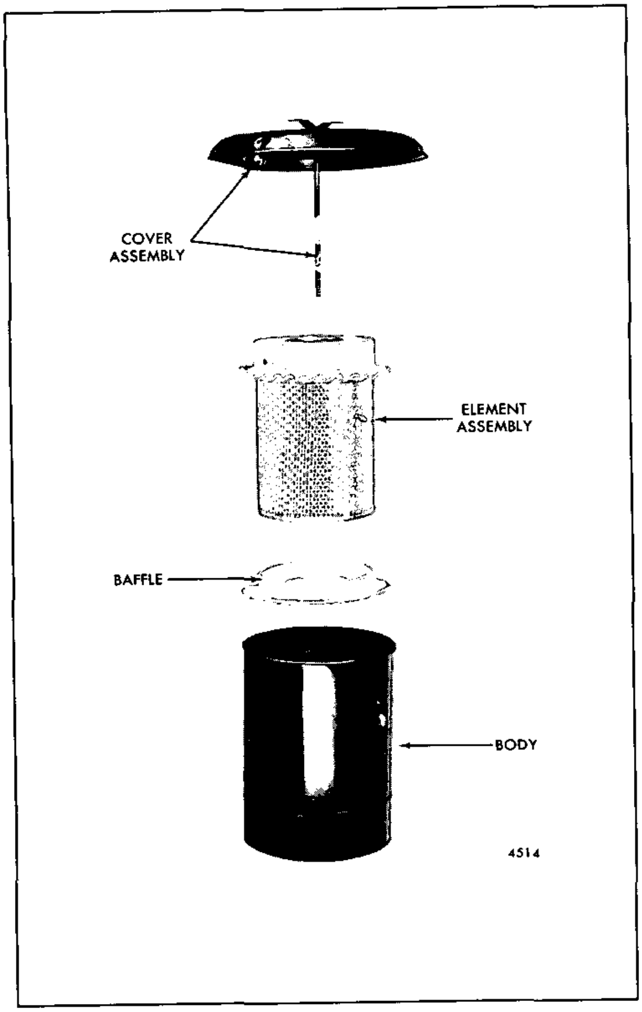


Fig. 7 – Dry Type Air Cleaner

Service (Dry Type)

The air cleaner should be serviced as operating conditions warrant. See Section 15.1 for element change intervals.

Under no engine operating conditions should the maximum allowable air intake restriction shown in Section 13.2 of the service manual be exceeded. Check restriction with a water manometer using the procedure outlined under "final RUN-IN" in Section 13.2.1. In addition, inlet restriction should be adjusted for high altitude conditions (see Table). *A clogged air cleaner element will* cause excessive intake restriction, reduce air supply to the engine, poor performance and higher valve and cylinder temperatures.

Disassemble the cleaner as shown in Fig. 7 as follows:

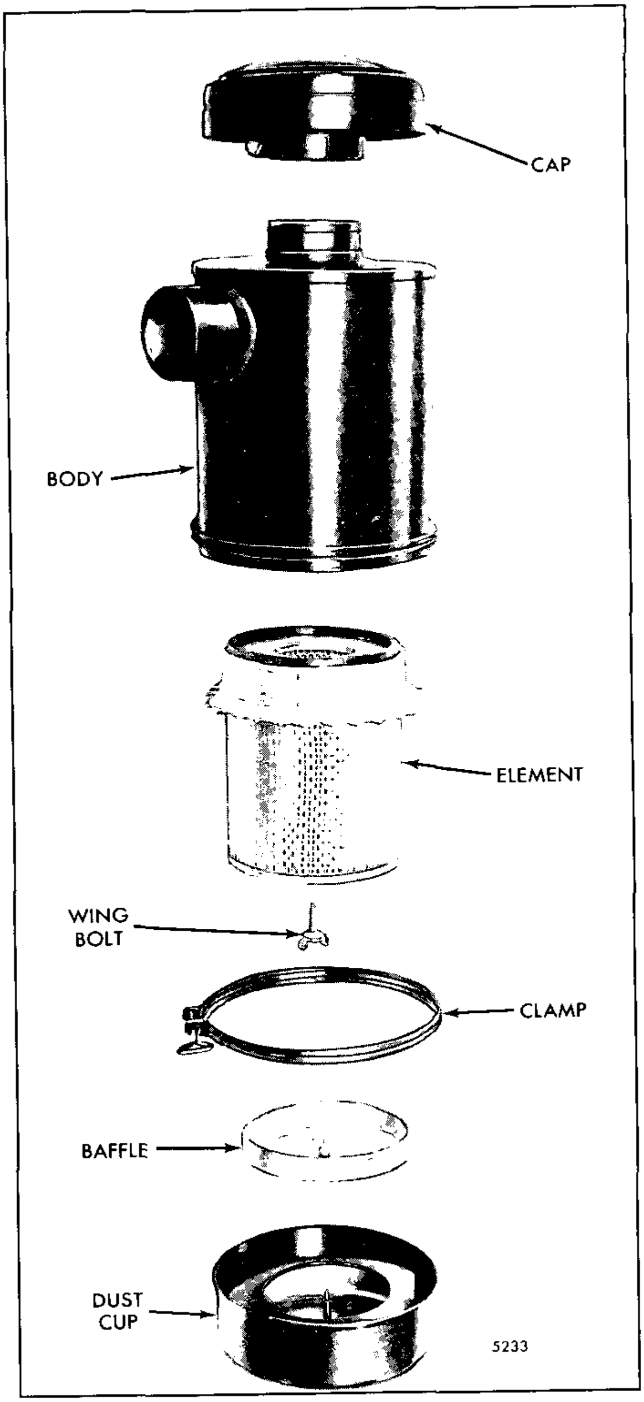


Fig. 8 – Dry Type Air Cleaner (Heavy Duty)

1. Loosen the cover bolt and remove the cover and bolt as an assembly.
2. Remove the element assembly and baffle from the cleaner body.

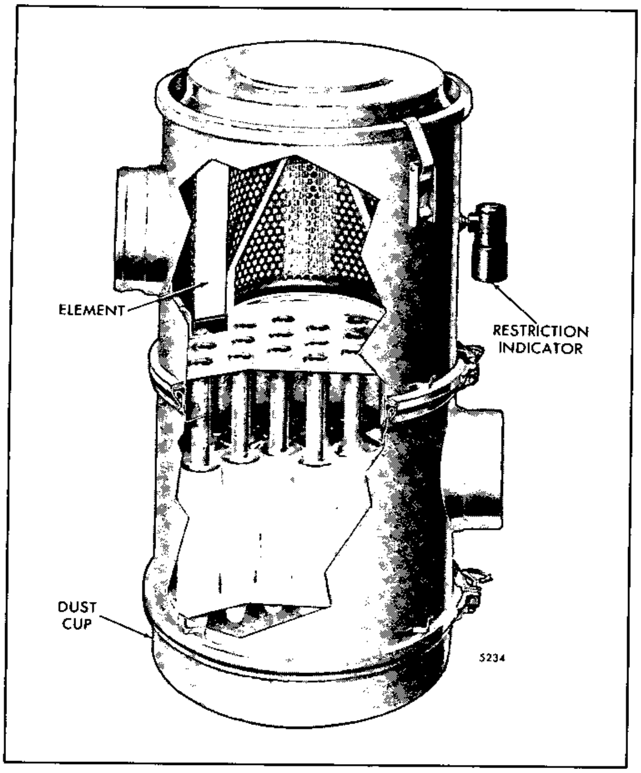
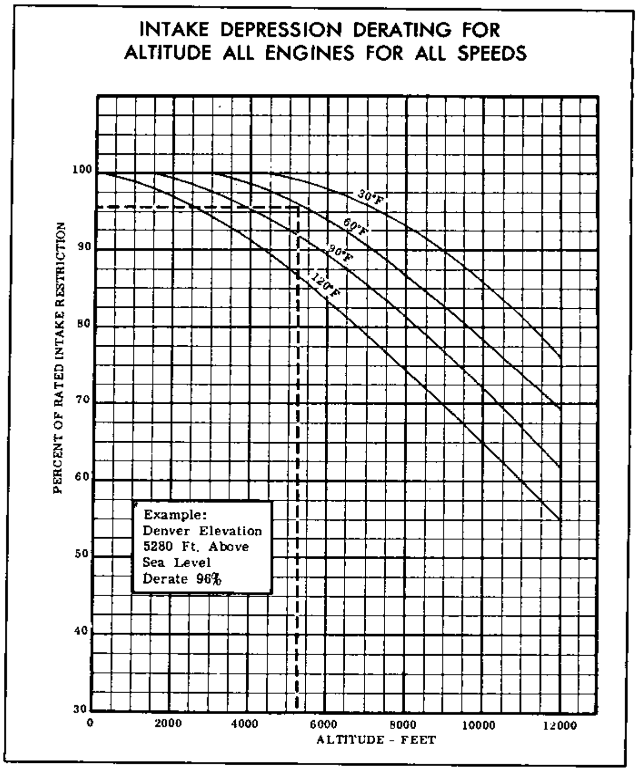


Fig. 9 – Dry Type Air Cleaner (Extra Heavy Duty)



TABLE

3. Remove the dust and clean the cleaner body thoroughly.

Disassemble the cleaner in Fig. 8 as follows:

1. Loosen the dust cup clamp and remove the dust cup.
2. Loosen the wing bolt in the dust cup and remove the baffle from the dust cup.
3. Remove the wing bolt from the cleaner body and remove the element assembly. The pre–cleaning fins are not removable.
4. Remove the dust and thoroughly clean the cleaner body, dust cup and baffle.

The paper pleated element assembly can be cleaned as follows:

1. The element can be dry cleaned by directing clean air up and down the pleats on the clean air side of the element. Maintain a reasonable distance between the nozzle and the element.

• **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

2. To wash the element, use the Donaldson Filter Cleaner or a non–sudsing equivalent. Proportions are 2 ounces of cleaner to 1 gallon of water. For best mixing results, use a small amount of cool tap water then add it to warm (100° F or 38° C) water to give the proper proportion. Soak the element for 15 minutes, then rinse it thoroughly with clean water from a hose (maximum pressure 40 psi or 135 kPa). Air dry the element completely before reusing (a fan or air draft may be used, but *do not heat* the element to hasten drying).

The filter manufacturer has no control over the field cleaning method or procedure. Therefore, it is the responsibility of the person or shop cleaning the element to assure the reliability of the filter after cleaning. It is also the responsibility of the installer to assure proper sealing of the gaskets.

Donaldson advises that elements used in on–highway applications should not be washed or reused. The reason for this is that on–highway trucks operate in an environment contaminated by a mixture of fine dust and exhaust carbon. To better enable dry type air cleaners to handle this type of contaminant, most on–highway truck air cleaners contain special chemically treated elements. Washing can remove the chemical treatment and shorten element life.

Consequently, on–highway air cleaner elements should not be washed and reused.

Most Donaldson primary elements used in off–highway applications do not receive the same chemical treatment. These can be cleaned and reused according to the manufacturer's recommendations. Secondary (safety) elements should not be cleaned or reused.

3. Inspect the cleaned element with a light bulb after each cleaning. Thin spots, pin holes, or the slightest rupture will admit sufficient air borne dirt to render the element unfit for further use and cause rapid failure of the piston rings. Replace the element assembly if necessary.
4. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

Reassemble the air cleaner in reverse order of disassembly. Replace the air cleaner body gasket, if necessary.

NOTICE: Do not use oil in the bottom of the cleaner body.

The element assembly should be replaced after six (6) cleanings, or annually.

Element Life

The recommended product life (shelf life plus service life) of Donaldson dry type air cleaner elements is three years. Consequently, Donaldson elements should be put into service no later than two years from the date of manufacture. Farr air cleaner elements should be put into service within one year from the date of manufacture.

AIR SILENCER

IN–LINE NATURALLY ASPIRATED ENGINES

The air silencer (Fig. 1) is attached to the intake side of the blower housing to reduce the sound level of the air entering the blower.

A perforated sheet metal partition divides the silencer into two sections. The engine side of the partition and the outer shell forms an air duct the entire length of the silencer. Air enters this duct from both ends and flows to the blower intake opening at the center. The area between the partition and the outer side of the silencer is filled with sound absorbent, flame–proof, felted cotton waste.

An air intake (blower) screen is used between the air silencer and the blower housing to prevent foreign objects from entering the blower.

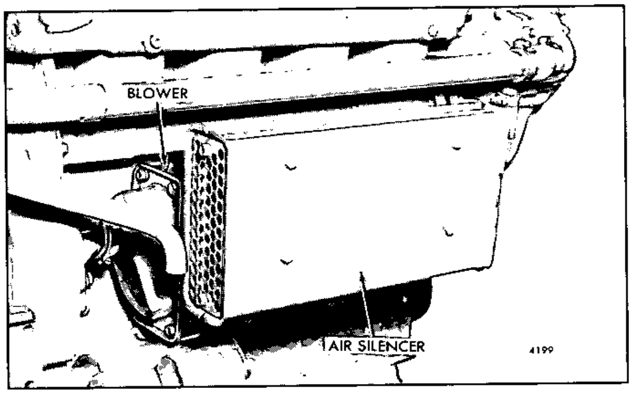


Fig. 1 – Air Silencer Mounted on In–Line Engine

Remove and Install Air Silencer

While no servicing is required on the air silencer, it may be necessary at times to remove it to clean or replace the blower screen or to perform other service operations.

1. Support the silencer and remove the attaching bolts and lock washers. Then remove the silencer and the blower screen.
2. Clean the blower screen with fuel oil and dry it with compressed air.
3. Place the blower screen on the 6V engine blower housing and install the air silencer adaptor.
4. Place the lock washers over the bolts and slide the bolts through the bolt holes in the silencer.
5. Place the blower screen (In–line engines) over the projecting bolts and position the silencer against the blower housing. Then tighten the bolts.

6V TURBOCHARGED AND 8V ENGINES

The air silencer (Fig. 2) is mounted on a support bracket. On naturally aspirated 8V engines, the air outlet end is attached to the air inlet housing with a hose and clamps. On turbocharged 6V and 8V engines, the air silencer is attached to the air inlet (compressor end) of the turbocharger with a hose and clamps. An air filter element of polyurethane foam is used on the current air silencer inlet screen.

Remove Air Silencer

While no servicing is required on the air silencer, it may be necessary to remove it to perform other service operations.

1. Remove the air filter element, if used.
2. Loosen the clamps and slide the hose back on the air inlet housing.
3. Loosen the lower bolts which secure the mounting straps to the silencer support bracket. Then, while holding the silencer, remove the bolts and washers. Remove the silencer.

Install Air Silencer

1. If previously removed, attach the mounting straps to the top of the silencer support bracket. Do not tighten the bolts at this time.
2. Position the air silencer under the mounting straps and install the 3/8"–16 bolts, lock washers, washers and nuts. Do not tighten the bolts at this time.
3. Align the silencer with the air inlet housing or turbocharger compressor inlet, slide the hose in place and tighten the clamps.
4. Tighten the mounting strap bolts at this time.
5. Install the breather pipe clip.
6. Slide the air filter element (if used) over the silencer air inlet screen.

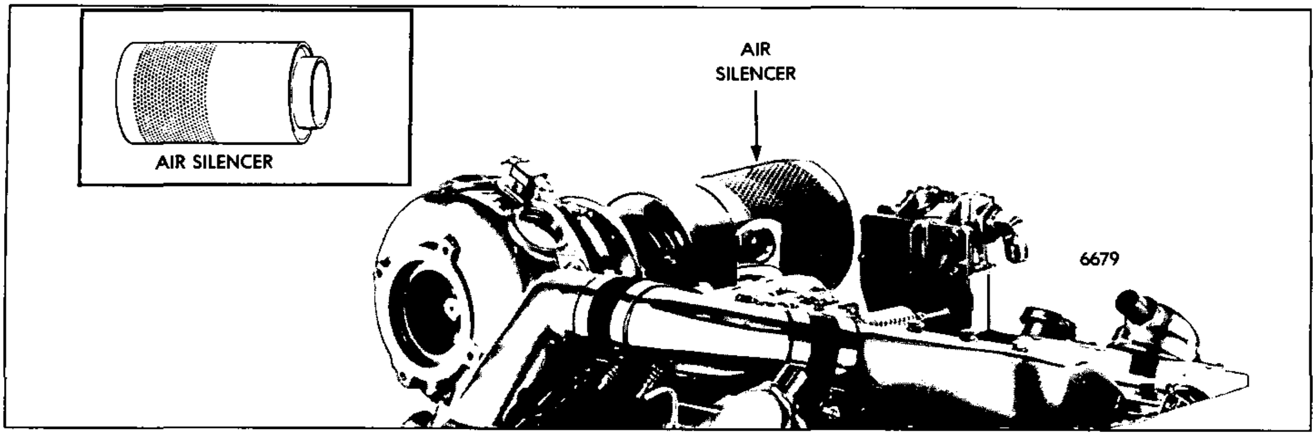


Fig. 2 – Air Silencer Mounted on 6V Turbocharged Engine

AIR SHUTDOWN HOUSING

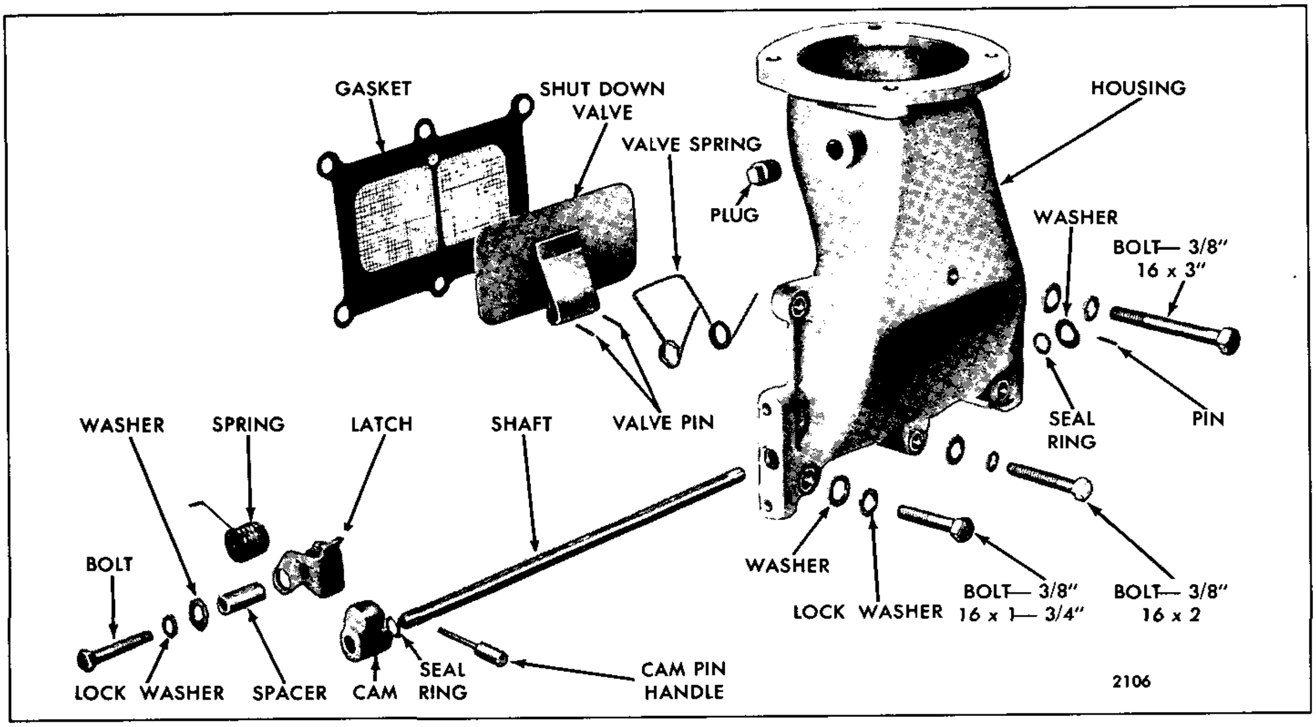


FIG. 1 – Typical In–Line Engine Air Shutdown Housing Details and Relative Location of Parts

The air shutdown housing on the in–line engine is mounted on the side of the blower, while the V–type engine has the air shutdown housing mounted on the top of the blower. The housing serves as a mounting for the air cleaner or the ducting for an air cleaner mounted away from the engine. The air shutdown housing contains an air shut–off valve that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut down.

Remove Air Shutdown Housing

1. Disconnect and remove the air ducts between the air cleaner and the air shutdown housing.
2. Disconnect the control wire from the air shut–off cam pin handle.
3. Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shutdown housing gasket from the blower.

   The bolts that retain the air inlet housing to the blower are of different lengths. Mark the location of each bolt to insure proper installation later.
4. Cover the blower opening to prevent dirt or foreign material from entering the blower.

Disassemble Air Shutdown Housing

Refer to Fig. 1 and disassemble the air shutdown housing as follows:

1. Remove the pin from the end of the shutdown shaft. Then remove the washer from the shaft and the seal ring from the housing.
2. Remove the two pins that secure the air shut–off valve to the shaft.
3. Remove the bolt, lock washer and plain washer which attach the latch to the housing. Then remove the latch, latch spring and spacer.
4. Note the position of the air shut–off valve spring and the valve (Fig. 2). Then withdraw the shaft from the housing to release the valve and the spring. Remove the valve and spring and the seal ring from the housing.
5. Remove the cam pin handle and withdraw the cam from the shaft.

Inspection

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the parts for wear or damage. The face of the air shut–off valve must be perfectly flat to assure a tight seal when it is in the shutdown position.

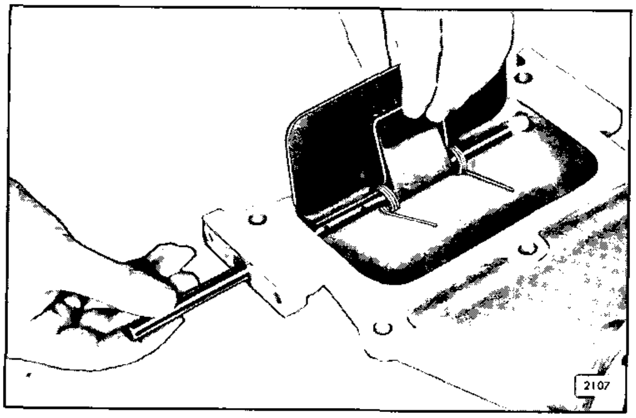


Fig. 2 – Installing Air Shut–Off Valve Spring and Valve

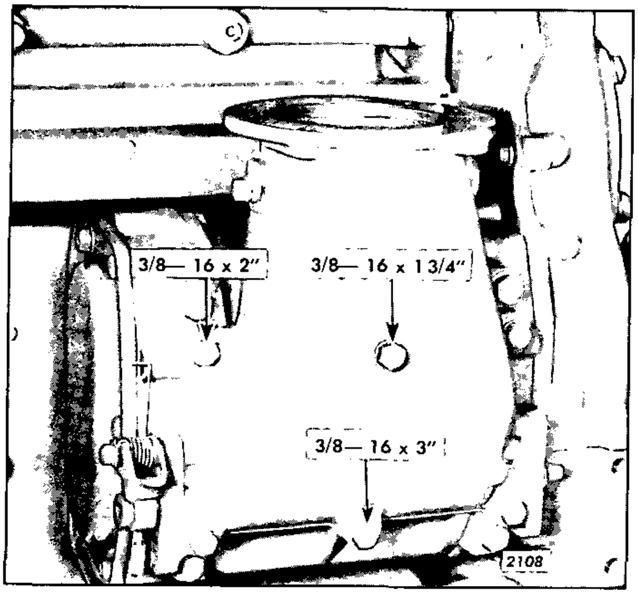


Fig. 3 – Location of Air Shutdown Housing Mounting Bolts (In–Line Engines)

Assemble Air Shutdown Assembly

The holes for the cam pin handle and the retaining pins must be drilled, using a 1/8" diameter drill, at the time a new service shaft or air shut–off valve(s) is assembled. The valve(s) must be in the same plane within .030" when in the stop position (flush with the housing face). Refer to Figs. 1 and 2 and proceed as follows:

1. Place the valve(s) and spring in position in the housing (Fig. 2) and slip the shaft in place. The shaft must extend .700" from the side of the housing where the shutdown latch is assembled.
2. Install a new seal ring at each end of the shaft. Be sure the seals are seated in the counterbores of the housing.
3. Install the cam and cam pin handle on the shaft.
4. Install a washer and retaining pin at the other end of the shaft.
5. Assemble the spacer (bushing), spring and latch to the shutdown housing with the 1/4"–20 bolt, lock washer and plain washer.
   a. Align the notch on the bushing with the notch on the latch and lock the bushing in this position.
   b. Install the pins in the valve(s) to retain it to the shaft with the cam release latch set and the valve(s) in the run position.
   c. Level the valve(s) in the shutdown position.
   d. Adjust the bushing so the valve(s) contacts the housing when the cam release latch is set.

Install Air Shutdown Housing (In–Line Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.
2. Refer to Figs. 1 and 3 and secure the air shutdown housing to the blower with bolts, washers and lock washers as follows:
   a. Install and finger tighten the six attaching bolts shown in Fig. 3.
   b. Tighten the two center bolts to 16–20 lb–ft (22–27 N·m) torque.
   c. Then tighten the four corner bolts to 16–20 lb–ft (22–27 N·m) torque.

   A power wrench should not be used to tighten the above bolts.

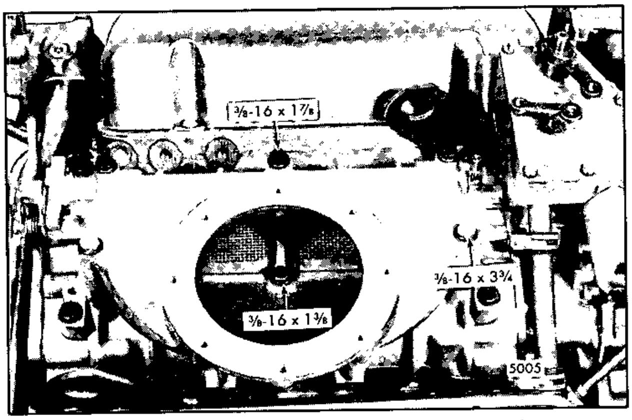


Fig. 4 – Location of Air Shutdown Housing Mounting Bolts (6V Engines)

3. Reset the air shutdown to the run position.

4. Start and run the engine at idle speed and no load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valve and the gasket. If necessary, reposition the valve.

Install Air Shutdown Housing (6V–53 Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Fig. 4 and mount the air inlet housing on the blower and secure it with bolts, washers and lock washers. Tighten the bolts to 16–20 lb–ft (22–27 N·m) torque.

3. Reset the air shutdown to the run position.

4. Start and run the engine at idle speed and no load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valves and the gasket. If necessary, reposition the valves.

Install Air Shutdown Housing and Adaptor (8V–53 Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Fig. 5 and install the air shutdown housing adaptor on the screen and gasket assembly. Install the six bolts and lock washers and tighten them to 16–20 lb–ft (22–27 N·m) torque.

3. Affix a new gasket on the top of the air inlet housing adaptor, then place the air shutdown housing on top of the gasket. Install the six bolts and lock washers and tighten them to 16–20 lb–ft (22–27 N·m) torque.

4. Reset the air shutdown to the run position.

5. Start and run the engine at idle speed and no load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valves and the gasket. If necessary, reposition the valves.

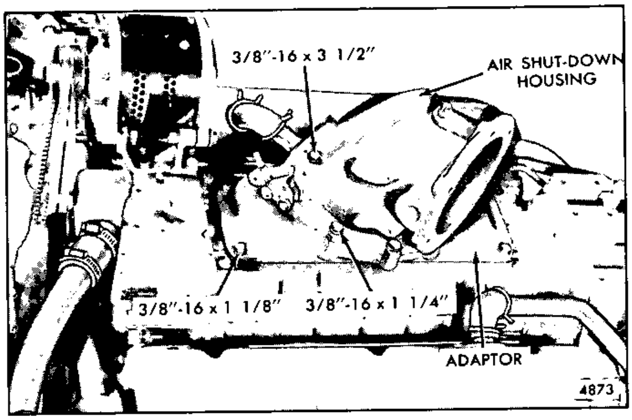


Fig. 5 – Location of Air Shutdown Housing and Adaptor Mounting Bolts (8V–53 Engines)

BLOWER

IN-LINE AND 6V ENGINES

The blower supplies the fresh air required for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow double-lobe rotors revolve in a housing bolted to the side of the In-line engines (Fig. 1) or on top of the cylinder block between the cylinder banks on the 6V engine (Fig. 2). The revolving motion of the rotors provides a continuous and uniform displacement of air.

The blower rotors are pinned to the rotor shafts. The rotor shafts are steel and the blower end plates are aluminum, providing for a compatible bearing arrangement.

Gears located on the splined end of the rotor shafts space the rotor lobes with a close tolerance. Since the lobes of the two rotors do not touch at any time, no lubrication is required.

The blower upper rotor gear of the 2-53 and 3-53 engines meshes with either the camshaft or balance shaft gear. The 4-53 and 6V engines have a blower drive gear.

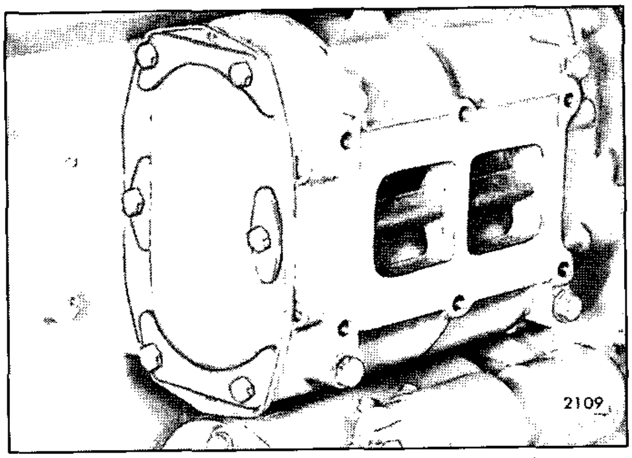


Fig. 1 – Blower Mounting (3-53 Engine)

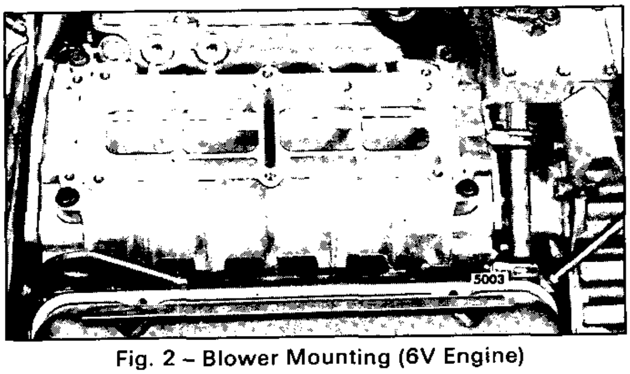


Fig. 2 – Blower Mounting (6V Engine)

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616. When replacing the former blower drive gears with the new, both gears must be changed.

Lip type oil seals are used in both the front and rear end plates on current engines. The seals prevent air leakage past the blower rotor shaft bearing surfaces and also keep the oil, used for lubricating the blower rotor gears, from entering the rotor compartment. Former blowers used a ring type oil seal consisting of a fiber washer, "O" ring, retainer and seal spring in each end of the blower rotors.

The Brazilian built engines used a blower assembly with a shorter housing and rotors for reduced capacity. Turbocharged engines use the Teflon® oil seal while the naturally aspirated engines built in Brazil used the polyacrylic oil seal. Only the Teflon® blower oil seal is serviced. An oversized lip type oil seal and a blower rotor shaft sleeve are available to increase life on the sealing surface of the blower rotor shaft.

Effective with engine serial numbers 4D-201579 and 6D-220736, new carbonitride-hardened blower drive shaft and a new steel induction-hardened blower coupling cam are being used in naturally aspirated and turbocharged engines. Carbonitride hardening results in added resistance to shaft and coupling spline wear. To distinguish the new shafts from the former, one end of each new shafts is stamped with the letter "H". The non-counterbored face of the new cam is stamped with the letter "S". The former and the new components are not interchangeable, and only the new components will be serviced.

Effective with engine serial numbers 3D-191032, 4D-204949 and 6D-225858, bypass blowers are used on all Series 53 turbocharged industrial engines.

A spring-loaded bypass relief valve is positioned in a passage in the front (3-53 and 4-53 engines) or rear (6V engines) blower end plate (Figs. 21 and 22). This valve is closed at start-up and during low rpm/light load operation. However, as engine speed and load increase, turbocharger speed also increases until the turbocharger provides sufficient boost pressure for scavenging and charging the engine cylinders. At 10″ Hg (34 kPa) airbox pressure the valve in the passage begins to open and is fully open at 13″ Hg (44 kPa). With the valve in the *open* position, incoming air is allowed to flow through the lobes of the blower and through the end plate to the airbox. The blower continues to

operate with the valve open, but requires less engine power because the pressure rise across the blower is greatly reduced. This results in decreased brake specific fuel consumption and increased fuel economy.

The bypass blower valve is externally vented back into the crankcase by means of a small hose and tube through the blower end plate. A very small amount of air bleeds past the valve and psses through the hose to help keep the valve clean and functioning properly. This has no effect on crankcase pressure.

Inspect Blower (Attached to Engine)

The blower may be inspected without removing it from the engine. However, the air cleaner and the air inlet housing must be removed.

CAUTION: To avoid personal injury when inspecting the blower with the engine running, keep your fingers and clothing away from the moving parts of the blower and run the engine at low speeds only.

Dirt or chips drawn through the blower will make deep scratches in the rotors and housing. Burrs around such abrasions may cause interference between the rotors or between the rotors and the blower housing.

Leaky oil seals are usually indicated by the presence of oil on the blower rotors or inside surfaces of the blower housing. Run the engine at low speed and direct a light into the rotor compartment and toward the end plates and the oil seals. A thin film of oil radiating away from a seal indicates an oil leak.

A worn blower drive resulting in a loose, rattling sound within the blower may be detected by running the engine at approximately 500 rpm.

Loose rotor shafts or worn rotor shaft bearing surfaces will result in contact between the rotor lobes, the rotors and the end plates, or the rotors and the housing.

Excessive backlash between the blower rotor gears usually results in the rotor lobes rubbing throughout their entire length.

Remove Blower

Before removing the blower from the engine, remove the air shutdown housing as outlined in Section 3.3.

2–53 and 3–53 ENGINE BLOWER

1. Remove the six bolts, special washers and reinforcement plates which secure the blower to the engine end plate and the flywheel housing. *Note the location of the two shorter bolts.* Then, remove the front end plate cover and gasket from the blower.
2. Remove the four blower–to–block bolts and special washers and lift the blower away from the engine.

4–53 ENGINE BLOWER

1. Loosen the clamp retaining the cover–to–support seal.
2. Remove the four blower–to–block bolts and special washers and lift the blower away from the engine, being careful not to damage the serrations on the blower drive shaft.

6V–53 ENGINE BLOWER

1. Disconnect the linkage to the governor control levers.
2. Remove the screws and lock washers which attach the governor cover to the governor housing. Remove the cover and gasket.
3. Remove the two bolts and lock washers which hold the spring housing to the governor housing. Remove the spring housing and gasket.
4. Remove the spring assembly from the governor.
5. Loosen the hose clamps and slide the hoses back on the fuel rod covers.
6. Clean and remove the valve rocker cover from each cylinder head. Discard the gaskets.
7. Disconnect the lower fuel rod from each injector control tube lever and also from each upper fuel rod.
8. Remove the threaded pins connecting the fuel rods to the control link lever. Remove the upper fuel rods.
9. Remove the blower drive cover plate. Remove the snap ring and withdraw the blower drive shaft from the housing.

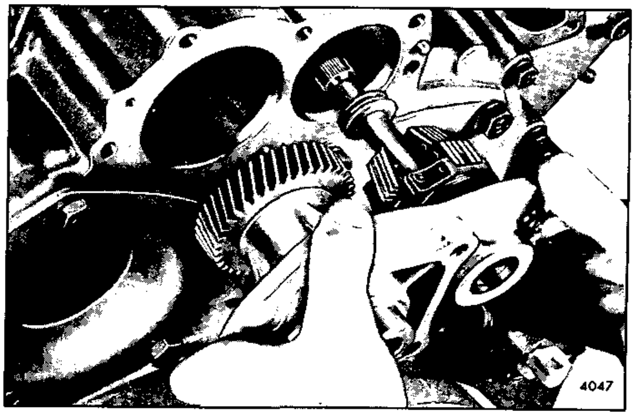


Fig. 3 – Removing/Installing Blower Drive Support (6V Engine)

10. Remove the two bolts and copper washers securing the blower drive support assembly. Then, withdraw the drive assembly until the splined end of the drive shaft is free from the drive plate (Fig. 3). Turn the drive assembly slightly so the serrated end of the governor weight shaft will pass around the governor operating fork. Remove the drive support from the engine.

11. The governor is doweled to the cylinder block rear end plate. Use a suitable tool to press or drive the dowel pin from the end plate.

12. Remove the four bolts and flat washers which attach the blower to the top face of the cylinder block. Lift the blower and governor assembly from the engine (Fig. 4).

13. Remove the six bolts and lock washers which attach the governor housing to the blower rear end plate. Remove the governor and gasket.

Disassemble Blower

2-53 and 3-53 ENGINE BLOWER

1. Wedge a clean cloth between the rotors to prevent their turning. Then, remove the blower gear retaining bolts and washers.

2. For identification, mark the R.H. helix gear. Then, remove the gears with pullers J 28483 as follows:

   a. With the pullers in place under the gears (Fig. 5), place a brass bar, approximately 1" long and 5/8" diameter, between the point of each puller bolt and blower rotor shaft.

NOTICE: If the brass bar is larger than 5/8" diameter, the serrations in the blower drive gear may be damaged.

   b. Alternately turn the bolt in each puller until the gears are off the shafts.

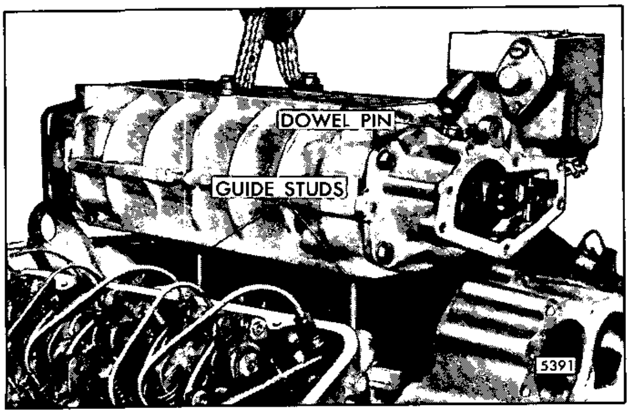


Fig. 4 – Removing/Installing Blower (6V Engine)

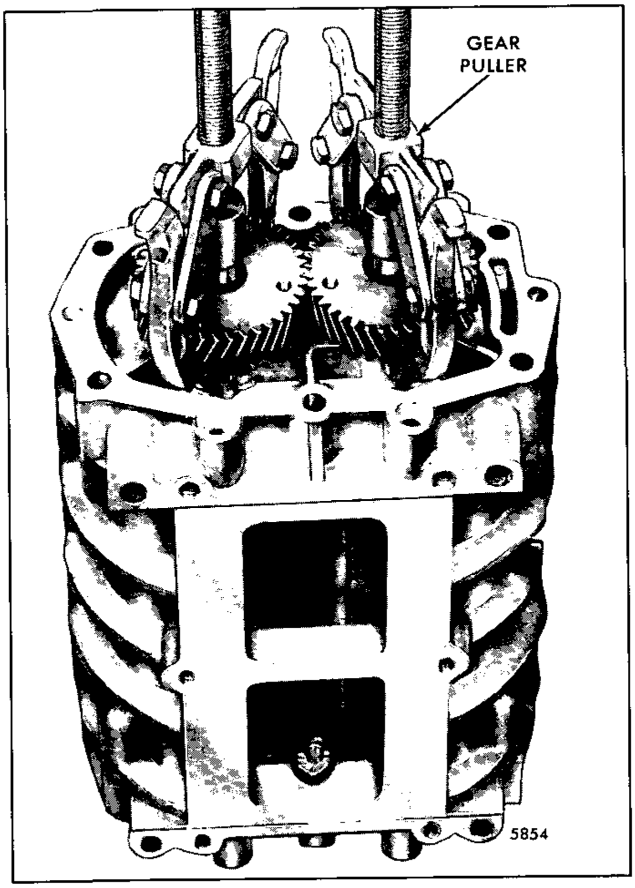


Fig. 5 – Removing Blower Rotor Gears

3. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct reassembly.

4. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers (refer to Fig. 6).

5. Remove the two screws that retain the end plate to the blower housing. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.

6. Remove the rotors from the blower housing.

7. Remove the retaining screws and remove the rear end plate as in Step 5.

8. Remove and discard the lip type oil seals from the end plates on current blowers. Remove the seal washer, "O" ring, retainer and retainer spring from each rotor shaft on former blowers.

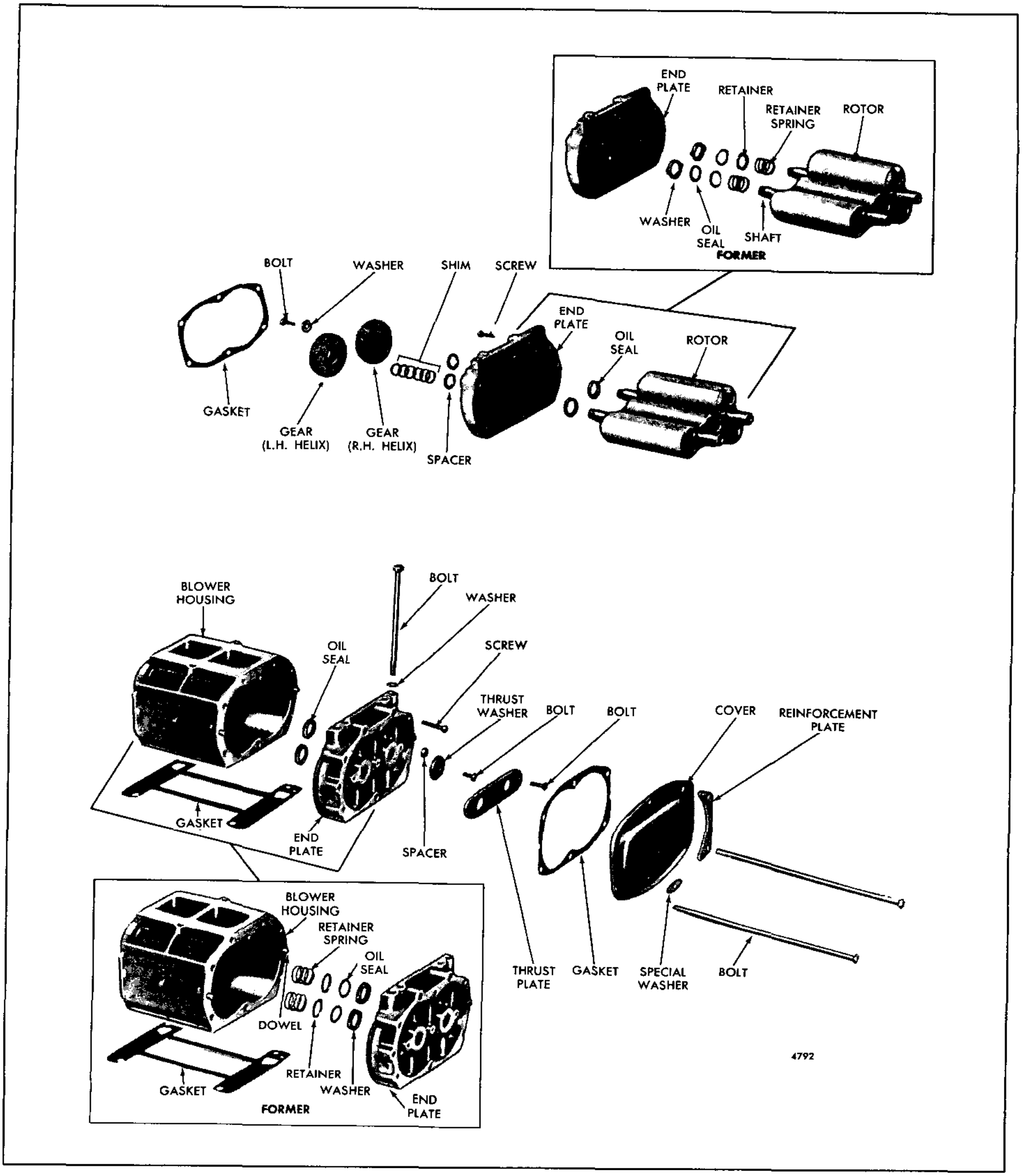


Fig. 6 – Typical Blower Details and Relative Location of Parts (3-53 Engine Blower)

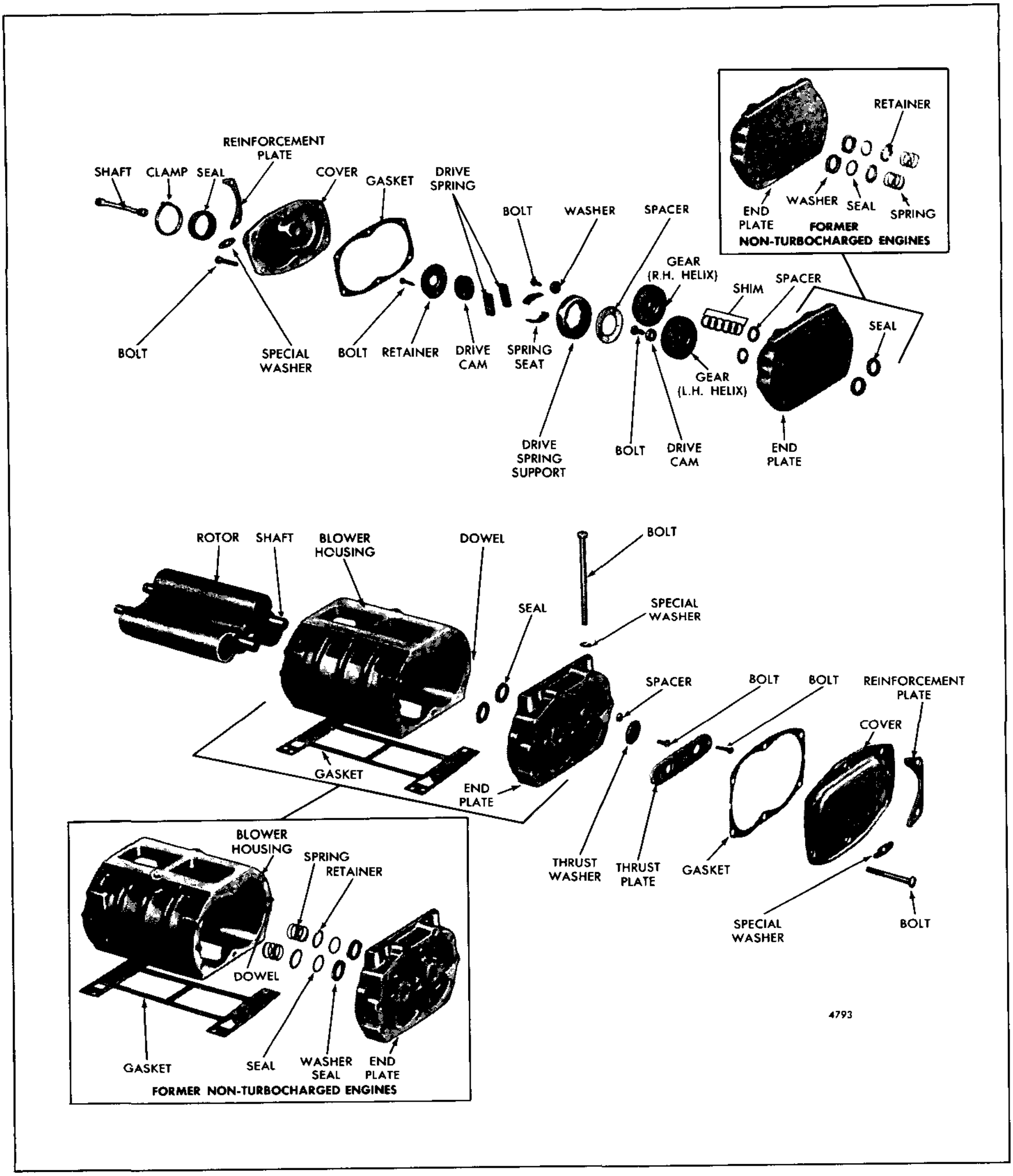


Fig. 7 – Typical Blower Details and Relative Location of Parts (4-53 Engine Blower)

9. If a bypass valve is used in the front end plate, disconnect the hose from the end plate. Remove the two bolts which secure the bypass valve in the end plate, then remove the bypass valve.

10. Clamp the bypass valve between the soft jaws of a vise and loosen the nut in the end of the valve. Remove the nut, spring and valve.

4–53 and 6V–53 ENGINE BLOWERS

1. Refer to Fig. 7 and remove the six bolts, special washers and reinforcement plates which secure the front end plate cover and the front end plate to the blower housing. Then, remove the end plate cover and gasket from the end plate.

2. On a 4–53 engine blower, remove the six bolts, special washers and reinforcement plates which secure the rear end plate cover and the rear end plate to the blower housing. Then, remove the end plate cover and gasket from the end plate. On the 6V engine, this step is accomplished by removing the governor.

3. Wedge a clean cloth between the rotors to prevent their turning and remove the four bolts that hold the blower drive cam retainer and blower drive spring support to the gear. Separate the retainer, support and spacer from the gear. On the 6V engine, the governor drive plate must also be removed from the opposite gear.

4. On a 4–53 engine blower, remove the retaining bolts and the washer and the blower drive cam pilot from the blower gears. On the 6V engine blower, a cam pilot is used on both gears.

5. For identification, mark the upper gear on the 4–53 blower or the left–hand gear on the 6V blower.

6. Use two pullers J 28483 to remove the two gears simultaneously.

7. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct reassembly.

8. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers.

9. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.

10. Remove the rotors from the blower housing.

11. Remove the rear end plate as in Step 9.

12. Remove and discard the lip type oil seals from the end plates on current blowers. Remove the seal washer, "O" ring, retainer and retainer spring from each rotor shaft on former blowers.

13. If required, disassemble the blower drive spring support by driving the cam from the support with a brass drift, permitting the springs and spring seats to fall free.

14. If a bypass valve is used in the front end plate, disconnect the hose from the end plate. Remove the two belts which secure the bypass valve in the end plate, then remove the bypass valve.

15. Clamp the bypass valve between the soft jaws of the vise and loosen the nut in the end of the valve. Remove the nut, spring and valve.

Inspection

Clean all of the parts thoroughly and dry with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

The finished inside face of each end plate must be smooth and flat. Slight scoring may be cleaned up with a fine grit emery cloth. If the surface is badly scored, replace the end plate.

Inspect the surfaces of the rotors and the blower housing. Remove burrs or scratches with an oil stone.

Examine the rotor shaft, gear or drive coupling for burred or worn serrations.

Inspect the blower gears for excessive wear or damage.

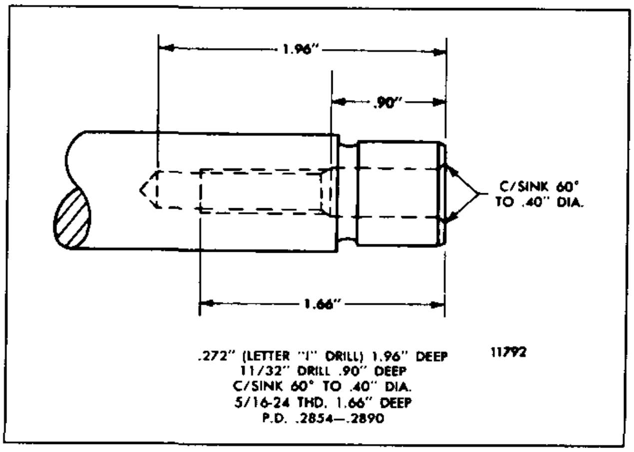


Fig. 8 – Dimensions for Reworking 6V Blower Rotor Shafts

Check the bearing and oil seal contact surfaces of the rotor shafts and end plates for scoring, wear or nicks.

If an oversize oil seal is required, a sleeve on the rotor shaft can be replaced as follows:

a. Place sleeve remover J 23679–2 over the rotor shaft and behind the oil seal sleeve.

b. Back out the center screw of one gear puller J 21672–4 and attach the puller to the sleeve remover with three 1/4″–20 x 3″ bolts and flat washers.

c. Turn the puller screw clockwise and pull the sleeve off of the shaft.

d. Support the rotor, gear end up, on the bed of an arbor press.

e. Start a new sleeve straight on the shaft.

f. Place sleeve installer J 23679–1 on top of the sleeve and press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft. The step in the sleeve installer properly positions the sleeve on the shaft.

The rotor assemblies for the 6V engine blower have been revised to permit the use of longer (1–3/4″) gear retention bolts. The former bolts were 7/8″ long. If a former blower is removed for repair or overhaul, rework the rotor shafts as illustrated in Fig. 8.

Assemble Blower

Current front and rear blower end plates can now be identified either of two ways:

Knowing the machining differences, such as thrust washer drilling, governor hole drilling, counterbores drilled, etc. (Fig. 9).

End plates are stamped with the last digit of its part number (Fig. 10). The end plate with a part number ending in 99 will have both numbers stamped in the plate.

Refer to Figs. 6 and 7 and assemble the blower as follows:

1. Install *new lip type oil seals* in each end plate in *current blowers* as follows:

   a. Place the end plate on the bed of an arbor press.

   b. Lubricate the outer diameter of the seal and, using installer J 22576, press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate (Fig. 11). A step on the seal installer will position the oil seal below the finished face of the end plate within the .002″ to .008″ specified.

2. Install *Teflon–lip oil seals* as follows:

   a. Press the oversize oil seal spacer onto the rotor shaft with installer J 23679–1 until either the shoulder of the tool or the spacer contacts the rotor.

   b. Support the blower end plate, finished surface up, on wood blocks on the bed of an arbor press.

NOTICE: Do not lubricate the seals, spacers, or blower rotor shafts prior to seal installation. Teflon lip seals *must* be installed dry. This allows transfer of the Teflon to the spacer surface for proper sealing.

   c. With the part number on the seal facing the rotor, start the oil seal straight into the bore in the end plate.

   d. Using installer J 22576, press the oil seal below the surface of the end plate until the shoulder of the installer contacts the end plate.

   e. Install the remaining oil seals in the end plates in the same manner.

No seal leakage should occur after the blower housing end plate Teflon oil seals are installed. If leakage does occur, the cause may be failure to install the seal dry. Teflon–lip blower end plate oil seals *must* be installed dry, without any prelubing.

3. Install the *ring type oil seals* on the rotor shafts of *former blowers* as follows:

   a. Install a retainer spring on each shaft of each rotor. Then, place an "O" ring retainer (dished side up) on each spring.

   b. Lubricate the "O" rings with clean engine oil, then slide one ring on each shaft.

   c. Lubricate and place a seal on each shaft. Note that the tangs on each seal are flush with one side of the seal; this side of the seal must face toward the rotor.

4. Two 5/16″ x 5/16″ steel plugs are used in the blower end plates of all *turbocharged* engines to ensure that a full–pressure flow of lubricating oil is supplied to the engine and to the oil galleries in the turbocharger center housing. The plugs (if removed) must be installed in the diagonally drilled orifices which supply additional lubrication to the blower drive gears. Plugs are pressed flush to .03″ below the surface of the end plates and staked in three places (Fig. 12). The plugs are not installed in the blower end plates of naturally aspirated engines.

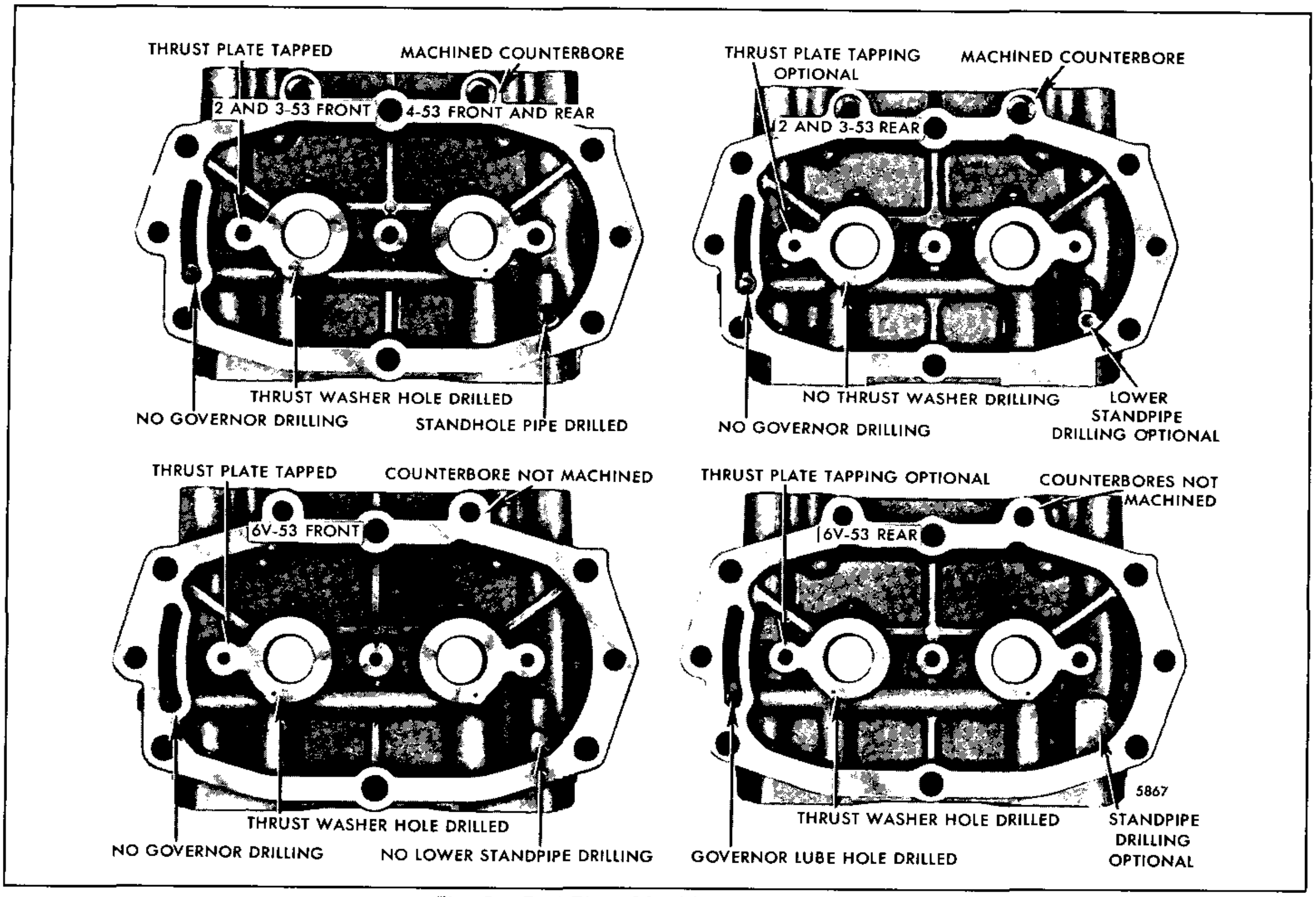


Fig. 9 – End Plate Machining Differences

NOTICE: Failure to install the plugs in the blower end plates of *turbocharged* engines can result in low engine oil pressure, inadequate turbo shaft bearing lubrication and serious engine or turbocharger damage.

5. Place the front end plate on two wood blocks. Then, install the rotors, gear end up, on the end plate (Fig. 13). On the former blowers, be sure that the ring type oil seals are properly positioned on the rotors.

6. Install the blower housing over the rotors (Fig. 14).

NOTICE: To prevent inadequate lubrication or low oil pressure, care must be exercised in the assembly of the front and rear blower end plates to the blower housing. The rear end plate for the *2–53 and 3–53 blower* does not have tapped holes for the thrust washer plate bolts and no thrust washer lubricating oil holes. The rear end plate for the *6V blower* does not have tapped holes for the thrust washer plates and is the only cover that has the horizontal oil passage drilled through into the pocket on the left side of the end plate for supplying oil to the blower drive gear support bearing.

7. Place the rear end plate over the rotor shafts (Fig. 15). On the former blowers, be sure that the ring type oil seals are properly positioned on the rotors. Then, secure each end plate to the 3–53 blower housing with two end plate retaining screws and two cover bolts and plain washers. Secure each end plate to the 4–53 or 6V blower with four end plate cover bolts and plain washers.

   Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .001" above to .004" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor–to–housing interference.

8. Attach the two thrust washers to the front end of the blower with the washer retaining bolts. If 5/16"–24 bolts are used, tighten them to 25–30 lb–ft (34–41

N·m) torque; if 3/8"–24 bolts are used, tighten them to 54–59 lb-ft (73–80 N·m) torque.

9. Attach the three spacers and the thrust plate to the front end of the blower. Tighten the three bolts to 7–9 lb-ft (10–12 N·m) torque. Then, check the clearance between the thrust plate and the thrust washers. The specified clearance is .001" to .003" (In–line engine blower) or .0025" to .0050" (6V engine blower).

   The current thrust plate is .260" thick. The former plate was .180" thick.

10. Position the rotors so that the missing serrations on the gear end of the rotor shafts are 90° apart. This is accomplished by placing the rotors in a "T" shape, with the missing serration in the upper rotor facing to the left and the missing serration in the lower rotor facing toward the bottom (Fig. 16). Install the shims and spacers in the counterbore in the rear face of the rotor gears. Then, place the gears on the ends of the shafts with the missing serrations in alignment with the missing serrations on the shafts.

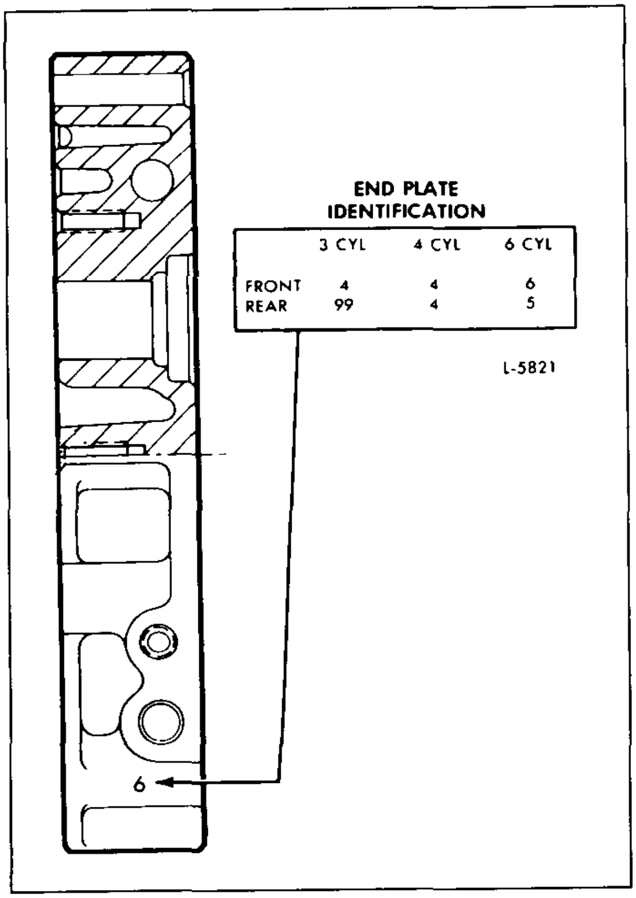


Fig. 10 – End Plate Identification

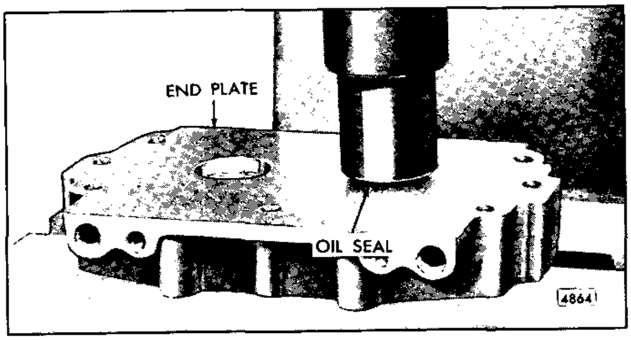


Fig. 11 – Installing Lip Type Oil Seal in End Plate with Tool J 22576

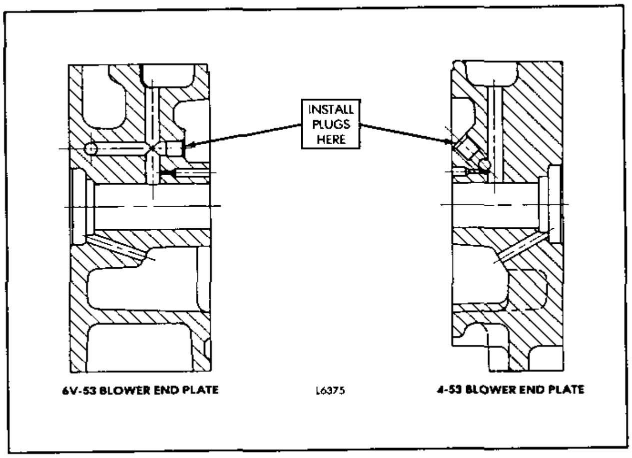


Fig. 12 – Location of Holes to be Plugged – Blower End Plates

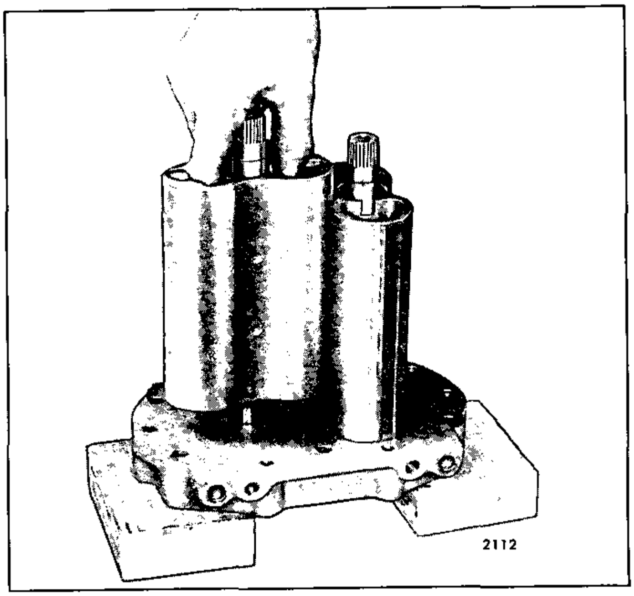


Fig. 13 – Installing Blower Rotors in Front End Plate

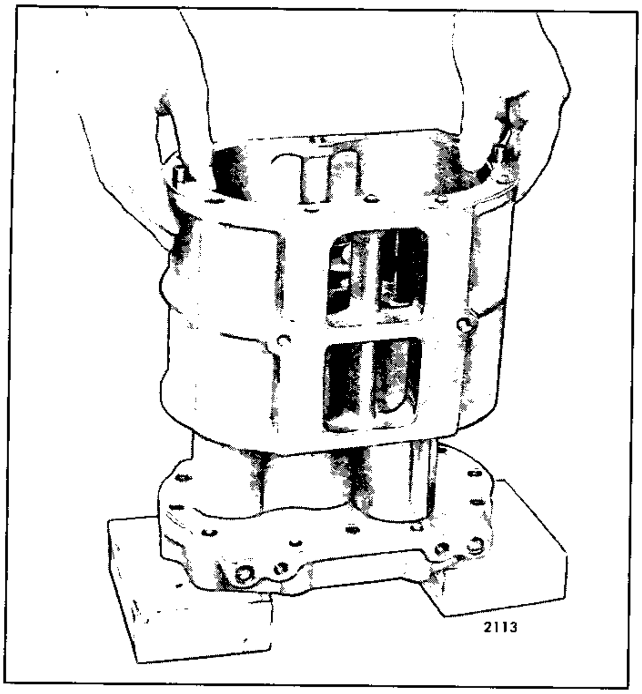


Fig. 14 – Installing Blower Housing Over Rotors

11. Tap the gears lightly with a soft hammer to seat them on the shafts. Then, rotate the gears until the punch marks on the face of the gears match. If the marks do not match, reposition the gears.

12. Wedge a clean cloth between the blower rotors. Use the gear retaining bolts and plain washers to press the gears on the rotor shafts (Fig. 17). Turn the bolts uniformly until the gears are tight against the shoulders on the shafts.

13. Remove the gear retaining bolts and washers. Then, proceed as follows:

    2–53 and 3–53 Blower — Place the gear washers on the gears and start the gear retaining bolts in the rotor shafts. Tighten the bolts to 25–30 lb–ft (34–41 N·m) torque.

    4–53 Blower — Place the blower drive cam pilot in the counterbore of the upper gear and start the gear retaining bolt in the rotor shaft. Place the gear washer on the face of the lower gear and start the gear retaining bolt in the rotor shaft. Tighten the bolts to 25–30 lb–ft (34–41 N·m) torque.

    6V–53 Blower — Place a pilot in the counterbore of each gear and start the 12–point bolt in the right–hand rotor shaft and start the hex head bolt in the left–hand rotor shaft. Tighten the bolts to 25–30 lb–ft (34–41 N·m) torque.

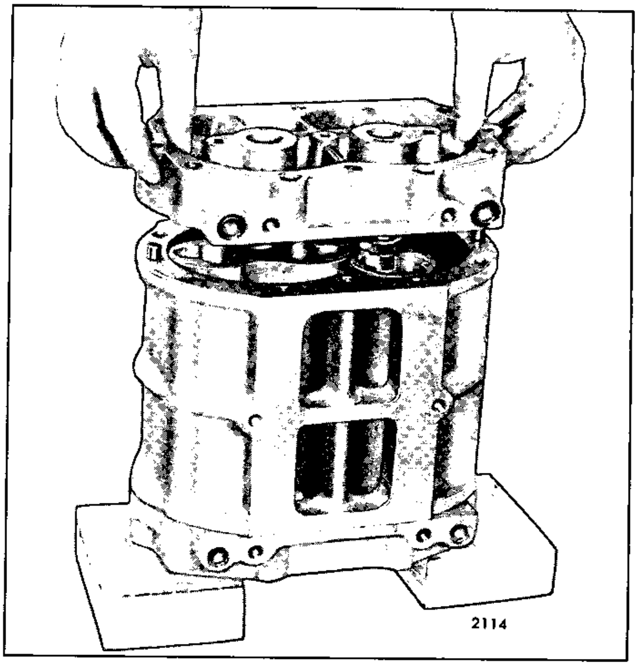
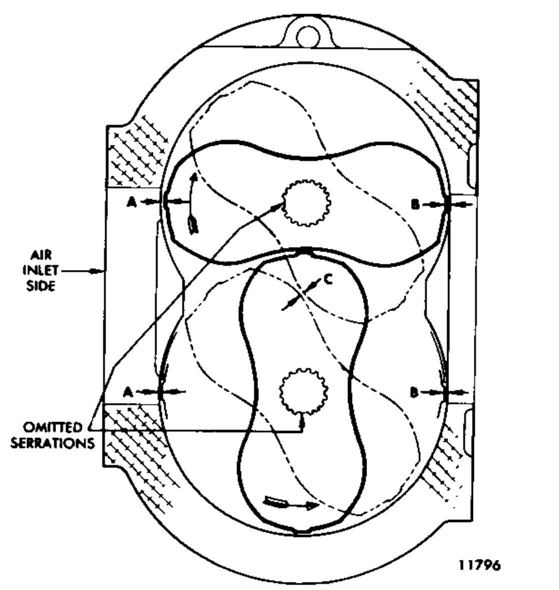


Fig. 15 – Installing Rear End Plate



	A	B	C
3-53	.010"	.004"	.010"
3-53T	.012"	.006"	.012"
4-53	.0075"	.004"	.010"
4-53T	.0075"	.007"	.010"
6V-53	.010"	.004"	.009"
6V-53T	.010"	.004"	.009"

Fig. 16 – Minimum Blower Rotor Clearance

14. Check the backlash between the blower gears, using a suitable dial indicator. The specified backlash is

.0005″ to .0025″ with new gears or a maximum of .0035″ with used gears.

15. Time Blower Rotors:

After the blower rotors and gears have been installed, the blower rotors must be timed. When properly positioned, the blower rotors run with a slight clearance between the rotor lobes and with a slight clearance between the lobes and the walls of the housing.

The clearances between the rotors may be established by moving one of the helical gears out or in on the shaft relative to the other gear by adding or removing shims between the gear hub and the rotor spacers.

It is preferable to measure the clearances with a feeler gage comprised of two or more feelers, since a combination is more flexible than a single feeler gage. A specially designed feeler gage set J 1698–02 for the blower clearance operation is available. Take measurements from both the inlet and outlet sides of the blower.

a. Measure the clearance between the rotor lobes and the housing (Fig. 18). Take measurements across the entire length of each rotor lobe to be certain that a minimum clearance of .004″ exists at the *air outlet side* of all blowers and a minimum clearance of .0075″ (In–line engine blower) or .010″ (6V engine blower) exists at the *air inlet side* of the blower (Fig. 16).

b. Measure the clearance between the rotor lobes, across the length of the lobes, in a similar manner. By rotating the gears, position the lobes so that they are at their closest relative position (Fig. 16).

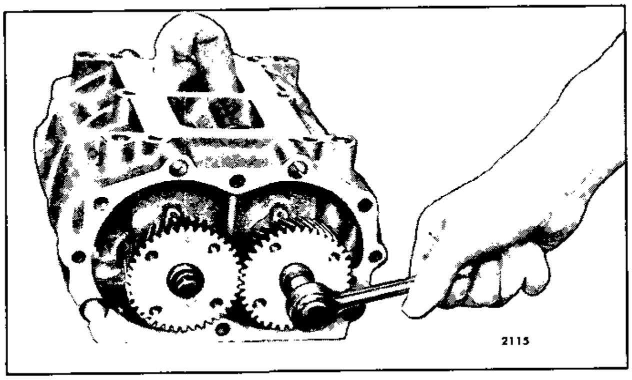


Fig. 17 – Installing Blower Rotor Gears

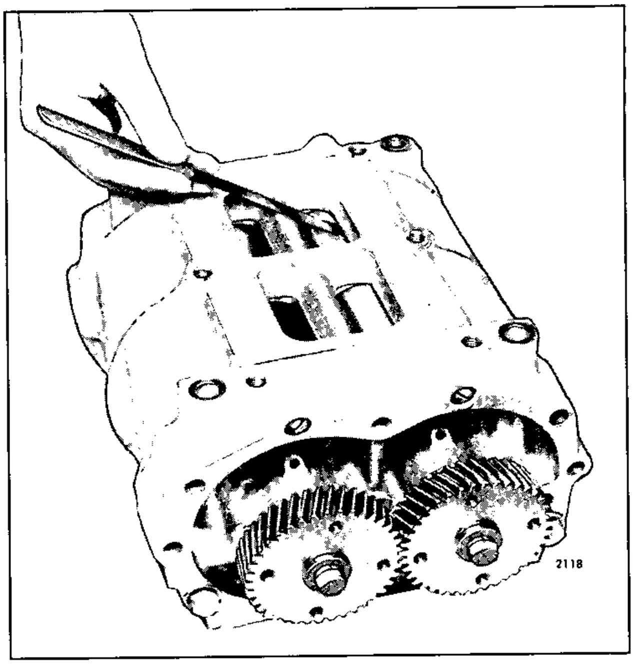


Fig. 18 – Measuring Rotor Lobe to Housing Clearance

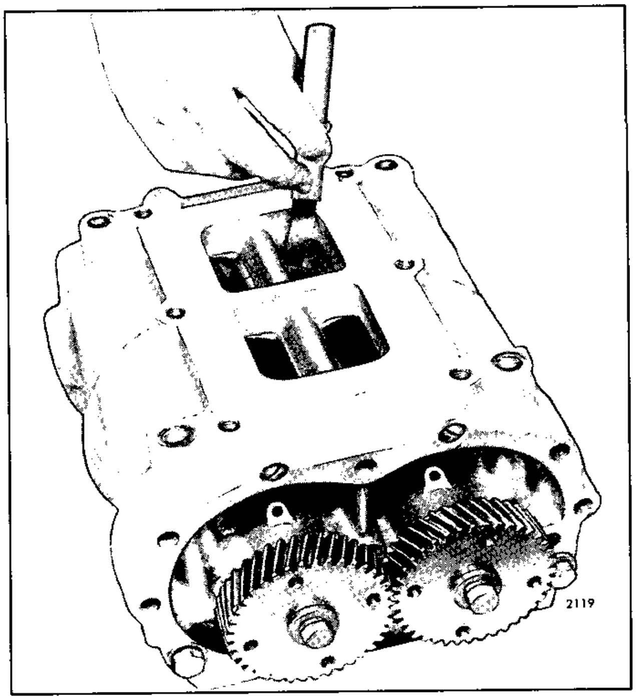


Fig. 19 – Measuring Rotor Lobe to End Plate Clearance

c. Measure the clearance between the end of the rotor and the blower end plate (Fig. 19). Refer to Table 1 for the required minimum clearances. Push and hold the rotor toward the

end plate at which the clearance is being measured.

After timing the rotors, complete assembly of the blower.

16. Remove the bolts and washers used to temporarily secure the front end plate to the housing. Then, install the front end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20–25 lb–ft (27–34 N·m) torque.

Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .001" above to .004" below the end plate. Excessive protrusion could distort the housing when the end plate to the cylinder block bolts are tightened and cause rotor to housing interference.

The current front and rear end plate gaskets on the 4–53 engine blower are identical and may be used in either position. Formerly, these gaskets were not interchangeable. The gasket used between the blower and the governor housing on the 6V engine is not interchangeable with the front end plate cover gasket.

17. Assemble the blower drive spring support as follows:

a. Place the drive spring support on two blocks of wood (Fig. 20).

b. Position the drive spring seats in the support.

c. Apply grease to the springs to hold the leaves together, then slide the two spring packs (15 leaves per pack) in place.

d. Place the blower drive cam over the end of tool J 5209, insert the tool between the spring packs and press the cam in place.

18. Install the drive spring support coupling on the rotor gear at the rear end of the blower.

Effective with engine serial number 4D–14120, the blower assembly for the 4–53 engine has been revised by the use of a new longer drive gear pilot and the addition of a drive coupling spacer (Fig. 21). Tighten the 5/16"–24 drive gear pilot bolt to 25–30 lb–ft (34–41 N·m) torque. Prior to the above change, a shorter drive coupling was used and no spacer was required.

The coupling is placed on the upper rotor gear on the In–line engine blower and on the left–hand gear on the 6V engine blower. A spacer is placed between the gear and the coupling on the 6V engine blower.

BLOWER ROTOR END CLEARANCES (Minimum)		
Engine	Front End Plate	Rear End Plate
3-53	.006"	.008"
3-53T	.008"	.009"
4-53	.006"	.009"
4-53T	.008"	.010"
6V-53	.008"	.010"
6V-53T	.010"	.012"

TABLE 1

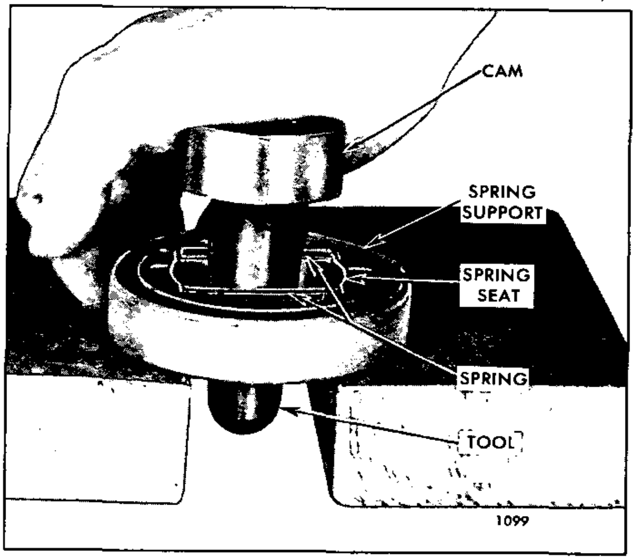


Fig. 20 – Inserting Cam in Blower Drive Support with Tool J 5209

19. Secure the cam retainer to the coupling with four 1/4"–28 bolts and tighten them to 14–18 lb–ft (19–24 N·m) torque.

20. On the 6V engine blower, install the governor drive plate on the right–hand rotor gear with four bolts and tighten them to 8–10 lb–ft (11–14 N·m) torque.

21. Remove the bolts and washer used to temporarily secure the rear end plate to the 4–53 engine blower. Then, install the rear end plate cover and gasket and secure the cover and end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20–25 lb–ft (27–34 N·m) torque.

This step is accomplished on the 6V engine blower by securing the governor to the end plate with six bolts.

Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .001" above to .004" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor–to–housing interference.

Install Blower

Examine the inside of the blower for any foreign material. Also, revolve the rotors by hand to be sure that they turn freely. Then, install the blower on the engine as follows:

2-53 and 3-53 ENGINE BLOWER

1. Affix a new blower–to–block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 1300, or equivalent, only on the block side of the gasket.
2. Position the blower front end plate and gasket on the end of the blower and install six bolts with two special washers on the center bolts and the reinforcement plates on the two top and two bottom bolts. Install a new engine end plate to blower gasket over the threaded ends of the bolts. Apply Scotch Grip Rubber Adhesive No. 1300, or equivalent to the engine end plate side of the gasket. The current front and rear end plate gaskets are identical and may be used in either position. Formerly, these gaskets were not interchangeable due to a difference in thickness.
3. Place the blower on the cylinder block locating flanges and, while holding the blower in place, thread the six bolts finger tight in the rear engine end plate and flywheel housing. Then, install the blower–to–block mounting bolts and washers and tighten them to 10–15 lb–ft (14–20 N·m) torque.

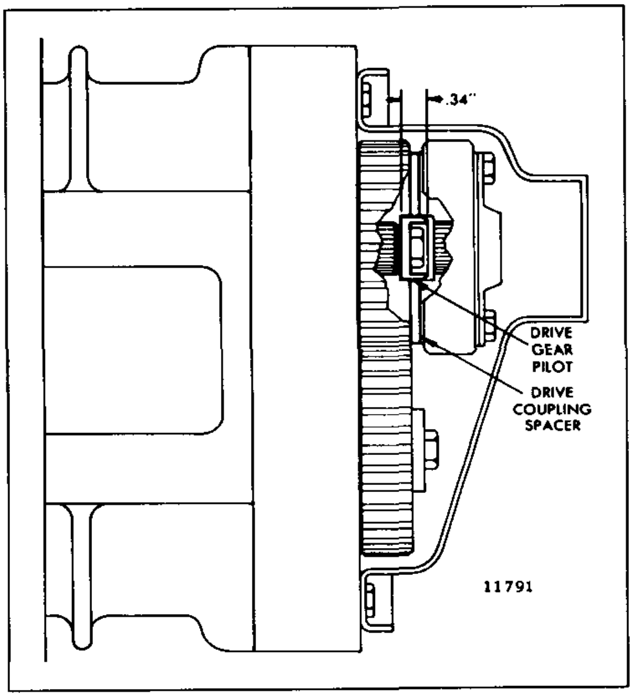


Fig. 21 – Current Pilot and Spacer Used on 4-53 Blower

4. Tighten the center blower–to–end plate bolts first, and then the top and bottom bolts to 20–25 lb–ft (27–34 N·m) torque. Then, tighten the blower–to–block bolts to 55–60 lb–ft (75–81 N·m) torque.
5. Check the backlash between the upper rotor gear and the camshaft or balance shaft gear. The backlash should be .003" to .007".
6. Install the air shutdown housing (Section 3.3).
7. If used, assemble and install the blower bypass valve as follows:
   a. Install the valve in the bypass valve body with the open end facing out. Then, install the spring and nut.
   b. Clamp the bypass valve body between the soft jaws of a vise and tighten the nut to 95–105 lb–ft (129–143 N·m).
   c. Install the bypass valve assembly in the blower end plate and connect the hose.
   d. Secure the bypass valve to the blower with clamps and bolts (Fig. 22).

4-53 ENGINE BLOWER

1. Affix a new blower–to–block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 1300, or equivalent, only on the block side of the gasket.
2. Install the seal and clamp on the blower rear end plate cover.
4. Position the blower on the side of the cylinder block. Use care so that the blower gasket is not damaged or dislocated during installation of the blower.
5. Secure the blower to the cylinder block with bolts and washers. Tighten the bolts to 55–60 lb–ft (75–81 N·m) torque.
6. Slide the seal and clamp back against the blower drive gear support and tighten the clamp to hold the seal in place.
7. Check the backlash between the blower drive gear and the camshaft gear. The backlash should be .003" to .007".
8. Install the air shutdown housing (Section 3.3).
9. If used, assemble and install the blower bypass valve as follows:
   a. Install the valve in the bypass valve body with the open end facing out. Then, install the spring and nut.

Fig. 22 – Typical Bypass Blower Valve Installation (In-Line Engine)

b. Clamp the bypass valve body between the soft jaws of a vise and tighten the nut to 95–105 lb–ft (129–143 N·m).

c. Install the bypass valve assembly in the blower end plate and connect the hose.

d. Secure the bypass valve to the blower with clamps and bolts (Fig. 22).

6V–53 ENGINE BLOWER

1. Install a new blower–to–block seal ring and two new blower–to–block gaskets. Affix the gaskets to the cylinder block and engine end plate with Scotch Grip Rubber Adhesive No. 1300, or equivalent.

2. Install the blower and governor assembly on the engine as follows:

NOTICE: Improper bolt down sequence can cause severe stresses which could result in failure of the main governor housing.

a. To install the blower and governor on the engine without disturbing the gaskets and seal, use guide studs (Fig. 4). Install the guide studs in the end blower bolt holes in the cylinder block.

b. While lowering the blower and governor assembly over the guide studs, push the blower away from the governor housing gasket attached to the rear end plate.

c. Remove the guide studs and install the blower to block bolts and flat washers. Tighten the bolts finger tight only.

d. Press or drive the governor housing dowel pin into the rear end plate with a suitable tool.

3. Secure the blower to the block with bolts and flat washers. Tighten the bolts to only 10–15 lb–ft (14–20 N·m) torque at this time.

4. Install the blower drive support as follows:

a. Affix a new gasket to the blower drive support.

b. Position the light governor weights (high–speed limiting–speed governor) in a horizontal position to provide clearance (Fig. 3). Turn the operating shaft fork away from the blower, if necessary, for additional clearance.

c. Move the blower drive assembly into the openings in the flywheel housing until the blower drive gear enters the housing. Then, turn the drive assembly slightly so that the serrated end of the governor weight shaft may pass around behind the governor operating fork, permitting the fork to slip into place between the serrated end of the shaft and the riser bearing.

d. Push the drive support assembly up against the flywheel housing; the serrations in the governor weight shaft and in the governor drive plate on the blower timing gear must mesh. The blower drive gear must also mesh with the mating gear.

5. Secure the small end of the blower drive support to the flywheel housing with two 3/8″–16 bolts and copper washers. Tighten the bolts to 20–24 lb–ft (27–33 N·m) torque.

6. Insert the blower drive shaft into the blower gear shaft. If necessary, turn the crankshaft so that the serrations on the blower drive shaft register with the serrations in the blower drive cam and the blower drive gear shaft.

7. Install the snap ring in the blower drive gear shaft to secure the blower drive shaft. The blower drive support and attaching accessories must be secured to the governor housing before final torque of the blower–to–block bolts.

8. Attach a new gasket to the blower drive support cover. Then, secure the cover to the support with four 3/8″–16 bolts and lock washers. Tighten the bolts to 20–24 lb–ft (27–33 N·m) torque.

9. Tighten the blower–to–block bolts to 55–60 lb–ft (75–81 N·m) torque.

10. If used, assemble and install the blower bypass valve as follows:

a. Install the valve in the bypass valve body with the open end facing out. Then, install the spring and nut.

b. Clamp the bypass valve body between the soft jaws of a vise and tighten the nut to 95–105 lb-ft (129–143 N·m).

c. Install the bypass valve assembly in the blower end plate and connect the hose.

d. Secure the bypass valve to the blower with clamps and bolts (Fig. 23).

11. Insert the upper fuel rods through the fuel rod covers and attach the rods to the governor control link lever.

12. Attach the lower fuel rods to the injector control tube levers and upper fuel rods.

13. Use new gaskets and reinstall the valve rocker covers.

14. Slide the fuel rod cover hoses in place and secure them with hose clamps.

15. Install the spring assembly in the governor.

16. Install the air shutdown housing (Section 3.3).

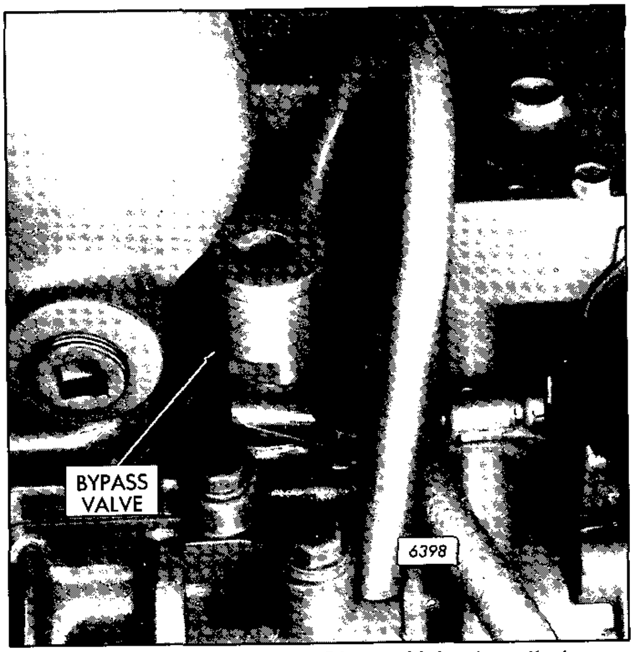


Fig. 23 – Typical Bypass Blower Valve Installation (6V Engines)

BLOWER (8V)

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear–type oil pump. Two hollow three–lobe rotors revolve with very close clearances in a housing mounted between the two banks of cylinders and bolted to the top deck of the cylinder block. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form (Fig. 1).

Two rotor gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals located in the blower end plates prevent air leakage and also keep the oil, used for lubricating the rotor gears and rotor shaft bearings, from entering the rotor compartment.

Effective with engine serial number 8D–4508, new blowers are used on the 8V engines. The current blowers differ from the former blowers in that the double–row ball bearings are now in the rear end plate (gear end) rather than the front end plate and the roller bearings are in the front end plate.

On the current blower, new rotors are used which have a counterbore for a cup plug in the balance holes to increase blower efficiency. Each rotor is supported in the end plates by a roller bearing in the front end plate and a two–row ball bearing at the gear end. The oil seal sleeves have been discontinued in the rear position of the non–turbocharged engine blower. The same oil seal is now used in both the front and rear end plates. The oil seal sleeves will continue to be used in both the front and rear end plates (four positions) in the turbocharged engine blower.

The right–hand helix rotor of an 8V blower is driven at approximately twice (2.205:1) engine speed by the blower drive shaft. The blower drive shaft is splined at one end to two flexible couplings attached to the blower drive gear and at the other end to a hub attached to the left–hand helix rotor drive gear. The mating right–hand helix rotor driven gear drives the left–hand helix rotor.

A flexible coupling, formed by an elliptical cam driven by four bundles of leaf springs which ride on four spring seats, is attached to the rear face of the blower drive gear and prevents the transfer of torque fluctuations to the blower.

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance, obtained by the use of shims behind the rotor gears, between the rotor lobes will not be maintained.

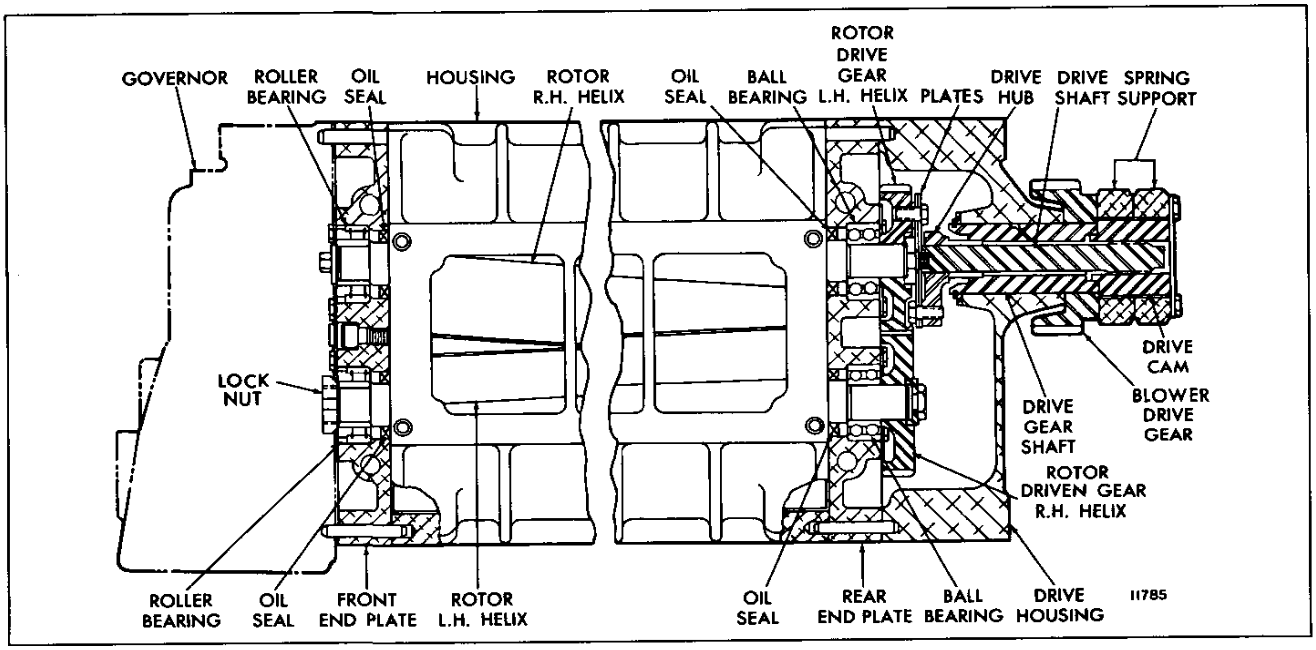


Fig. 1 – Current Blower and Drive Assembly

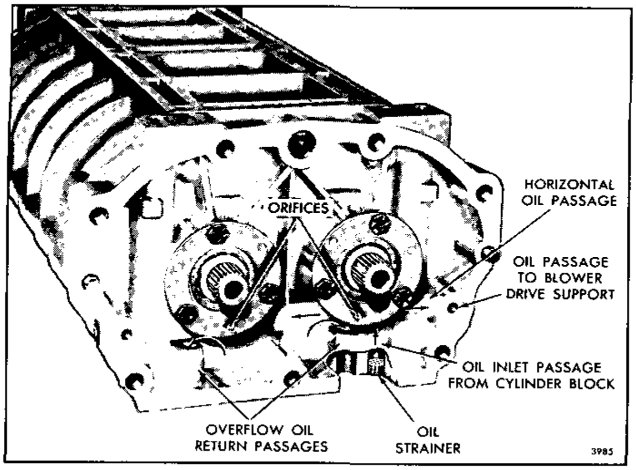


Fig. 2 – Blower Lubrication

Normal rotor gear wear causes a decrease of rotor–to–rotor clearance between the leading edge of the right–hand helix (drive) rotor and the trailing edge of the left–hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be corrected by adjustment, rotor gear backlash cannot be corrected. When rotor gears have worn to the point where the backlash *exceeds .004", replace the gears.*

Lubrication

The blower bearings, rotor gears and governor drive mechanism are pressure lubricated by means of oil passages in the top deck of the cylinder block which lead from the main oil galleries to an oil passage in each blower end plate (Fig. 2). The oil flows upward to the horizontal oil passage in the end plate and leaves through a small orifice just below each bearing bore in the end plate. The oil is ejected from these orifices against the rotor gears at the rear end of the blower and the governor weights at the front end of the blower.

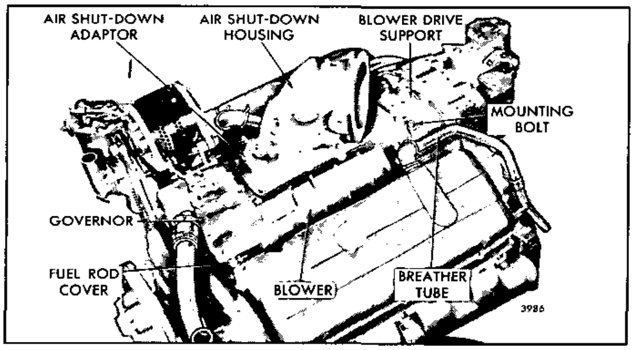


Fig. 3 – Typical Blower Mounting

The bearings are splash lubricated by oil thrown by the rotor gears and governor weights. Oil which collects at the bottom of each end plate overflows into two drain passages *which lead back to the crankcase via oil passages in the* cylinder block.

The blower drive support bearing receives oil under pressure from the horizontal oil passage in the blower rear end plate (Fig. 2) which leads to the oil passage in the blower drive support housing.

Inspection

The blower may be inspected without being removed from the engine. However, the air silencer and adaptor, or the air inlet housing, air shutdown housing and adaptor must first be removed.

- **CAUTION: To avoid personal injury when inspecting the blower with the engine running, keep your fingers and clothing away from the moving parts of the blower and run the engine at low speeds only.**

Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and remove the burrs to eliminate the interference, or replace the rotors if they are badly scored.

Leaky oil seals are usually manifest by the presence of oil on the blower rotors or the inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals is indicative of an oil leak.

A worn blower drive usually results in a rattling noise inside the blower and may be detected by grasping the right–hand helix rotor firmly and attempting to rotate it. Rotors may move from 3/8" to 5/8", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4". If the rotors cannot be moved as directed above, or if the rotors move too freely, inspect the flexible blower drive coupling and replace it if necessary. The drive coupling is attached to the left–hand helix rotor drive gear.

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. A loose shaft usually causes rubbing between the rotors and the end plates. Worn or damaged bearings will cause rubbing between the mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing. This condition will usually show up at the end where the bearings have failed.

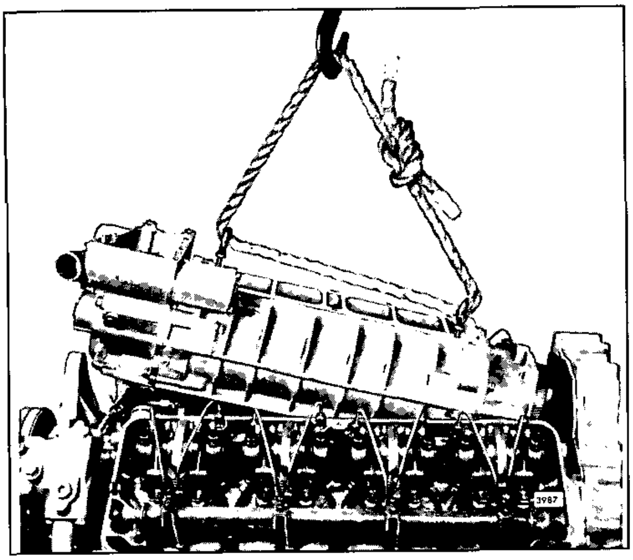


Fig. 4 – Removing Blower from Engine

Excessive backlash between the rotor gears usually results in rotor lobes rubbing throughout their entire length.

Inspect the blower inlet screen periodically for accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning it with a stiff brush until the screen is free of all dirt deposits.

To correct any of the above conditions, remove the blower from the engine and either repair or replace it.

Remove Blower

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The blower drive components are assembled in a combination blower drive housing and blower rear end plate cover. Therefore, when removing the blower assembly from the engine, the governor and blower drive support assemblies will also be removed at the same time. Refer to Fig. 1 and proceed as follows:

1. Disconnect the throttle control rods from the governor levers.

2. Remove the six bolts and lock washers securing the air shutdown housing to the air inlet adaptor. Remove the shutdown housing and gasket.

3. Remove the six bolts and lock washers securing the air inlet adaptor to the blower housing. Remove the air inlet adaptor and blower screen and gasket assembly.

4. Loosen the battery–charging generator adjusting strap bolt. Also loosen the nuts on the bolts securing the generator to its mounting bracket. Then remove the generator drive belts from the generator pulley.

5. While supporting the generator, remove the two nuts, lock washers and bolts securing the generator to the generator mounting bracket. Then lift the generator off the engine.

6. Remove the four bolts and lock washers securing the generator mounting bracket to the governor housing.

7. Loosen the governor housing breather tube hose clamp at the forward face of the governor and the breather tube clamp at the water pump attaching bolt. Remove the tube, hose and hose clamps from the governor and the engine.

8. Remove the four bolts and lock washers securing the water by–pass tube to the thermostat housing. Slide the tube back on one of the thermostat housings, then lift the opposite end of the tube up and remove it from the thermostat housing.

9. Disconnect and remove the fuel oil supply and return lines connecting the fuel manifolds and the cylinder heads.

10. Remove the valve rocker cover breather tube hose clamp on each rocker cover and the tube clamp attached to the rear face of the flywheel housing; then remove the breather tubes from the engine.

11. If an air compressor is attached to the rear face of the flywheel housing, it may be removed as follows:

    a. Disconnect the air compressor water inlet and outlet tubes from the air compressor. Then disconnect the oil supply line from the air compressor.

    b. While supporting the air compressor, remove the four bolts and lock washers securing the air compressor to the rear face of the flywheel housing. Then remove the air compressor and gasket. If necessary, remove the air compressor drive coupling.

12. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.

13. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.

14. Pull the blower drive shaft out of the blower drive hub and cam. If necessary, use a pair of small nose pliers.

15. Remove the two remaining bolts and flat washers securing the blower drive couplings to the blower drive gear, then remove the blower drive couplings.

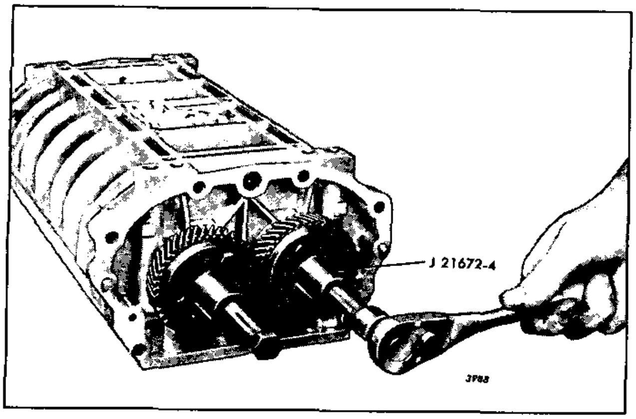


Fig. 5 – Removing Rotor Gears Using Tool J 21672–4

16. Remove the five bolts, lock washers and one plain washer securing the blower drive support housing to the engine end plate. 17. Disconnect and remove the fuel oil supply line between the fuel oil pump and the fuel oil filter.

18. Clean and remove the valve rocker cover from each cylinder head.

19. Remove the eight screws and lock washers securing the governor cover to the governor housing.

20. Disconnect the fuel rods from the injector rack control tube levers and the governor and remove the fuel rods.

21. Loosen the hose clamps and slide the fuel rod cover hose down against each cylinder head.

22. Remove the two 7/16"–14 x 7/8" bolts, lock washers and plain washers securing the governor housing to the cylinder block.

23. Remove the two bolts and special washers from each blower end plate securing the blower assembly to the cylinder block.

24. Thread eyebolts in diagonally opposite air inlet adaptor–to–blower bolt holes. Attach a rope sling and a chain hoist to the eyebolts. Then lift the blower assembly, at an angle, from the cylinder block as shown in Fig. 4 and place it on a bench.

Remove Accessories from Blower

Remove the accessories from the blower as follows:

1. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support housing to the blower rear end plate.

2. Tap each end of the blower drive support housing with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the drive support assembly and gasket.

3. Remove the three self–locking bolts (current blowers) or four self–locking bolts (former blowers) securing the blower drive hub to the left–hand helix rotor drive gear.

4. Remove the seven bolts and lock washers securing the breather body to the governor housing. Remove the breather body and gasket.

5. Remove the seven bolts and copper washers, two inside and five outside, securing the governor assembly to the blower front end plate.

6. Tap the governor housing with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the governor assembly and gasket.

Disassemble Blower

Cover the air inlet and outlet openings and clean the exterior of the blower with fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Refer to Figs. 3 and 10 and disassemble the blower as follows:

1. Place a clean folded shop towel between the rotors and a towel between the rotor and housing to prevent the rotors from turning.

2. Remove the two bolts and pilots (43) securing the blower rotor gears to the blower rotor shafts.

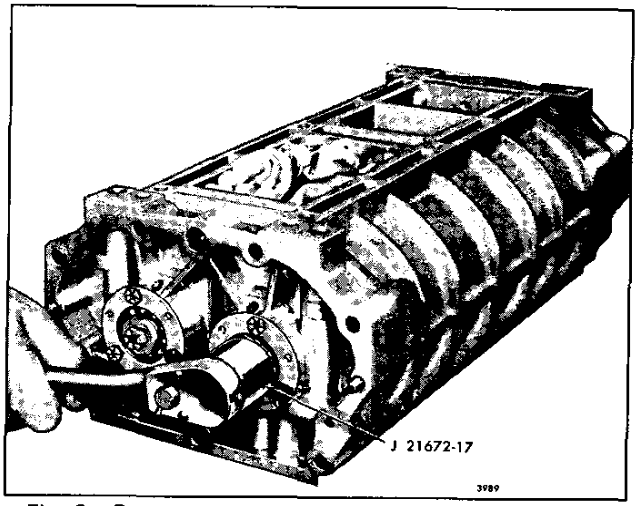


Fig. 6 – Removing Rotor Bearing Retaining Nut Using Tool J 21672–17

3. Remove the blower rotor gears with pullers J 21672-7 (Fig. 5). Both rotor gears must be pulled at the same time as follows:

   a. Back the center screws out of both pullers, then place the flange end of the pullers against the rotor gears. Align the large holes in the puller flanges with the 3/8"-24 tapped holes in the gears. Secure the pullers to the gears with four 3/8"-24 x 1" bolts.

   b. With the shop towels between the blower rotors and housing to prevent them from turning, turn the puller screws uniformly clockwise and pull the gears from the rotor shafts as shown in Fig. 5.

4. Remove the shims from the rotor shafts and note the number and thickness of the shims on one or both of the rotor shafts.

5. Remove the bolts securing the rotor shaft bearing retainers (71) to the rear end plate, then remove the retainers.

6. Remove the bolt and special washer (80) securing the ball bearing (former blower) or roller bearing (current blower) on the right-hand helix rotor shaft at the front end of the blower.

7. Bend the tang of the bearing retainer nut lock washer (81) up out of the notch in the bearing lock nut (82). Then remove the bearing lock nut with spanner wrench J 21672-17 as shown in Fig. 6.

8. Remove the bolts securing the rotor shaft bearing retainers to the front end plate, then remove the retainers.

9. Remove the socket head bolt (50) securing the blower rear end plate to the blower housing. Tap each end of the rear end plate with a plastic hammer to loosen it from the blower housing, then remove the end plate and bearings from the rotor shafts.

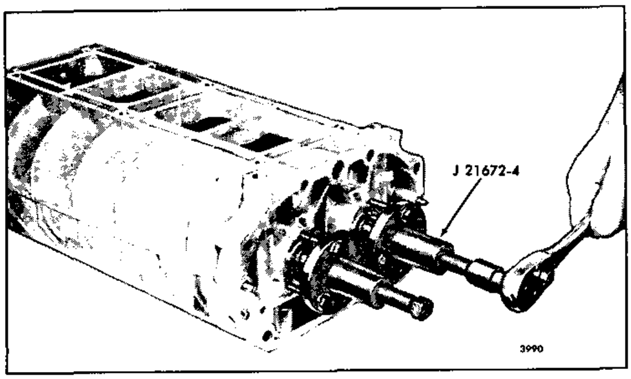


Fig. 7 – Removing Blower Rotors from Front End Plate Ball Bearings (Former Blower) Using Tool J 21672-4

10. Remove the blower rotors from the ball bearings (former blowers) and from the roller bearings (current blowers) in the front end plate and the blower housing as follows:

    a. Back the center screw out of both pullers J 21672-7, then attach the pullers to the blower front end plate with six 1/4"-20 x 1-1/2" or longer bolts as shown in Fig. 7.

    b. Remove the shop towels from between the blower rotors and the housing.

    c. Turn the puller screws uniformly clockwise and push the rotor shafts out of the ball bearings (former blower) or roller bearings (current blower) in the end plate. Then slide the rotors out of the blower housing.

    d. Remove the pullers from the blower front end plate.

11. Remove the socket head bolt securing the blower front end plate to the blower housing. Tap each end of the front end plate with a plastic hammer to loosen it and remove it from the blower housing.

12. Inspect the rotor shaft oil seals. If the seals are scored or hard, remove the bearings and oil seals from the blower end plates as follows:

    a. Support the blower end plate, inner face up, on two wood blocks on the bed of an arbor press as shown in Fig. 8.

    b. Place the oil seal remover J 21672-11 with handle J 7079-2 on top of the oil seal and under the ram of the press, then press the oil seal and bearing out of the end plate as shown in Fig. 8. Discard the oil seal.

    c. Remove the remaining oil seals and bearings from the end plates in the same manner as outlined in items "a" and "b" above.

    When the roller bearings are removed from the rear end plate, each bearing must be tagged to be sure it will be installed in the same bearing bore in the end plate that it was removed from.

    Oil seal sleeves have been discontinued in the rear position of the current non-turbocharged engine blower. The oil seal sleeves will continue to be used in both the front and rear end plates (four positions) in the turbocharged engine blower.

13. If the roller bearings or the oil seal sleeves are to be replaced, the roller bearing inner races and oil seal sleeves may be removed from the rotor shafts as follows:

The roller bearing inner race may be removed separately or the oil seal sleeve and inner race may be removed together.

a. Place the roller bearing inner race and oil seal sleeve remover J 21672–20 over the rotor shaft behind the oil seal sleeve as shown in Fig. 9.

b. Back out the center screw of one gear puller J 21672–7, then attach the puller to the oil seal sleeve remover with three 1/4″–20 x 3″ bolts and flat washers as shown in Fig. 9.

c. Turn the puller screw clockwise and pull the roller bearing inner race and oil seal sleeve off of the rotor shaft.

d. Remove the roller bearing inner race and oil seal sleeve from the remaining rotor shaft.

NOTICE: Be sure and tag or place each roller bearing inner race with its mating roller bearing. Do not intermix the inner races and roller bearings.

Inspection

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil. Then while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

The double–row ball bearings are pre–loaded and have no end play. A new double–row bearing will seem to have considerable resistance to motion when revolved by hand.

Examine the rotor shafts and the oil seal sleeves (used on former blowers and turbocharged engine blowers) for wear.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also inspect the bearing contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for flatness and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

Examine the serrations in the blower rotor gears for wear and peening; also check the teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds .004″ or damaged sufficiently to require replacement, both gears must be replaced as a set.

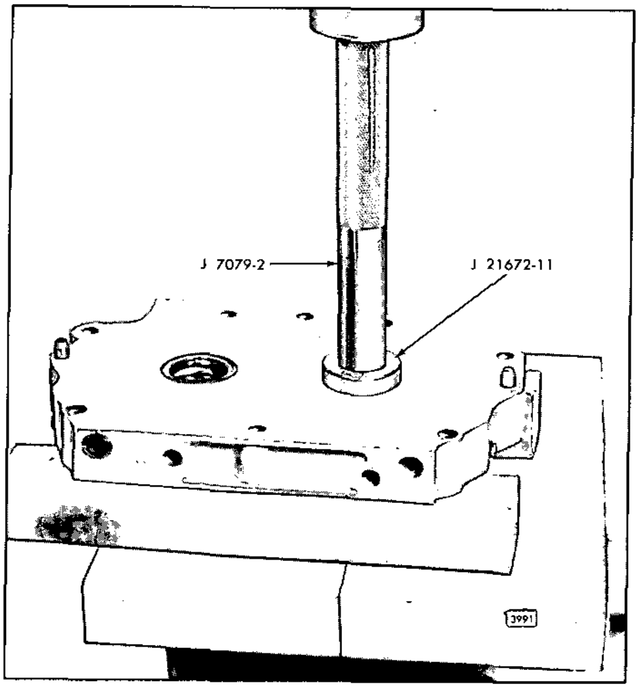


Fig. 8 – Removing Oil Seal and Roller Bearing from Rear End Plate (Former Blower) Using Tool J 7079–2

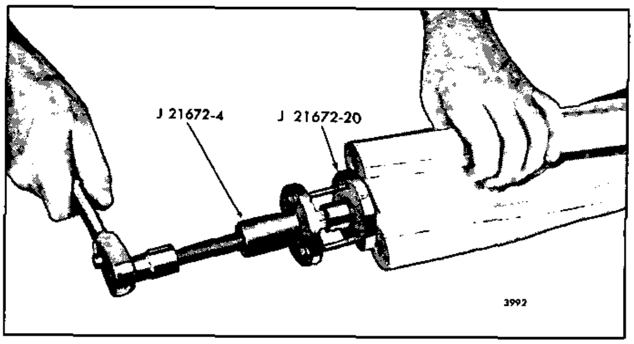
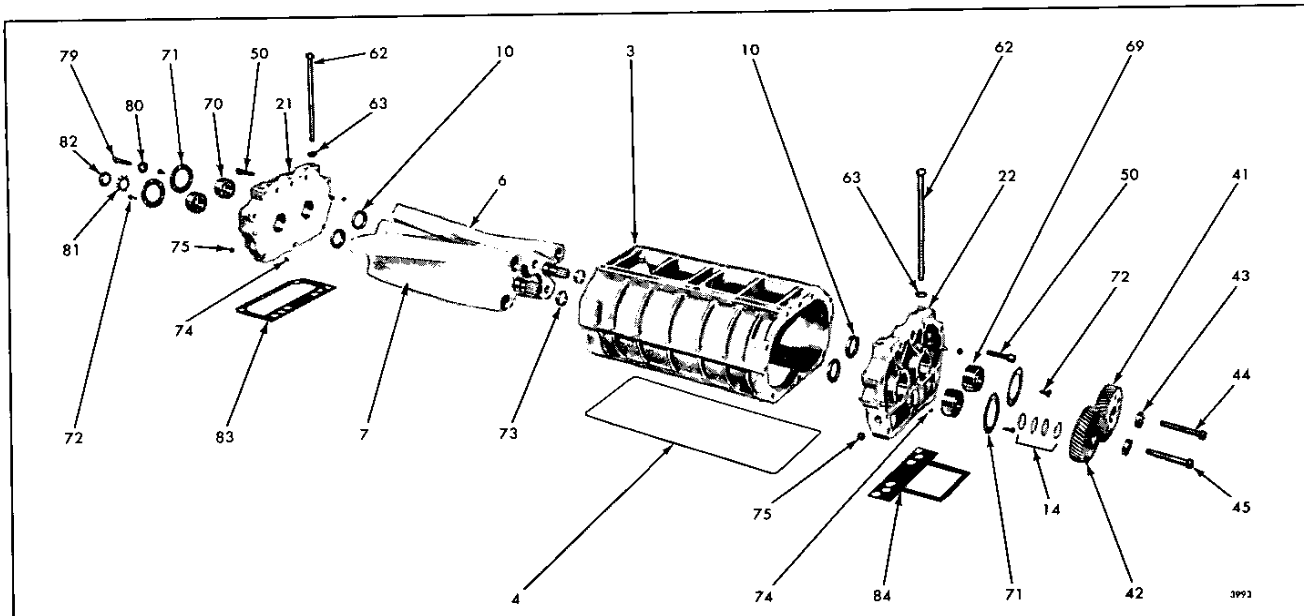


Fig. 9 – Removing Oil Seal Sleeve and Roller Bearing Inner Race from Rotor Shaft



3.	Housing—Blower	22.	Plate—Rear End	62.	Bolt—Blower-to-Block	74.	Strainer—End Plate Oil Passage
4.	Gasket	41.	Gear—Rotor Drive L.H. Helix	63.	Washer—Special	75.	Plug—Pipe
6.	Rotor Assy.—R.H. Helix	42.	Bear—Rotor Driven R.H. Helix	69.	Bearing—Rotor Rear (Roller)	79.	Bolt
7.	Rotor Assy.—L.H. Helix	43.	Pilot—Rotor Gear	70.	Bearing—Rotor Front (Ball)	80.	Washer
10.	Oil Seal—Rotor Shaft	44.	Bolt—Drive Gear	71.	Retainer—Bearing	81.	Lock Washer
14.	Shims	45.	Bolt—Driven Gear	72.	Bolt—Bearing Retainer	82.	Nut
21.	Plate—Front End	50.	Bolt—Socket Head	73.	Sleeve—Oil Seal	83.	Gasket
						84.	Gasket

Fig. 10 – Blower Details and Relative Location of Parts (8V-53) (Former Blower)

The left-hand helix rotor drive gear in the current blower has three bolt holes. The gear in the former blower has four bolt holes. This is due to the bolting arrangement (three bolt holes current drive hub, four bolt holes former drive hub) of the drive hub.

Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent.

Inspect the blower drive coupling springs (pack) and the cam for wear.

Replace all worn or excessively damaged blower parts.

Clean the oil strainer in the vertical oil passage at the bottom of each blower end plate and blow out all oil passages with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Assemble Blower

The lobes on the *driving* blower rotor form a right–hand helix and the teeth on its gear form a left–hand helix while the lobes on the *driven* blower rotor form a left–hand helix and the teeth of its gear form a right–hand helix. Hence, a rotor with right–hand helix lobes must be used with a gear having left–hand helix teeth and vice versa.

New rotors with a different helix angle have been incorporated in the 8V engine blowers. The former and new rotors must not be mixed in a blower assembly. The proper clearances cannot be obtained in a mix of the former and new rotors.

With this precaution in mind, proceed with the blower assembly, referring to Figs. 10 through 20 as directed in the text:

1. If removed, press a new oil strainer into the vertical oil passage at the bottom of each end plate from flush to .015" below the bottom surface (Fig. 2). Also, if removed, install a pipe plug in the horizontal oil passage at each end of both end plates.

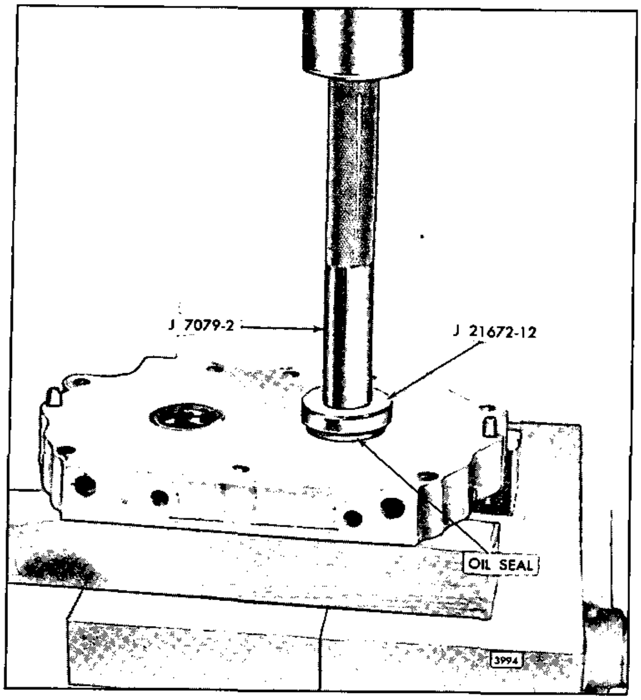


Fig. 11 – Installing Oil Seal in Rear End Plate (Former Blower)

2. Install new oil seals in the blower end plates as follows:

   a. Support the blower rear end plate, finished surface facing up, on wood blocks on the bed of an arbor press.

      The rotor shaft oil seals used in the former blower end plates have two different inside diameters. Install the oil seal with the largest inside diameter in the former blower rear end plate. On current blowers, the oil seal sleeves have been discontinued in the rear position, therefore the same oil seal is now used in both the front and rear end plates.

      The rear end plate may be identified by the bolt guide sleeve pressed into the right–hand bolt hole in the bottom of the end plate.

   b. Start the large inside diameter oil seal straight into the bore in the rear end plate with the lip of the seal facing down (toward the bearing bore).

   c. Place the oil seal installer J 21672–12 with handle J 7079–2 on top of the oil seal as shown in Fig. 11. Then press the oil seal straight into the end plate until the shoulder on the installer contacts the end plate.

   d. Install the second oil seal in the rear end plate and the oil seals in the front end plate in the same manner. The oil seals must be flush to .010" below the finished surface of the end plate.

3. If removed, install the rear end plate oil seal sleeve and the roller bearing inner race on the gear end of each blower rotor shaft as follows:

   a. Support the blower rotor, gear end up, on the bed of an arbor press as shown in Fig. 12.

   b. Start the oil seal sleeve straight on the sleeve surface of the shaft.

   c. Place the oil seal sleeve installer J 21672–16 on top of the oil seal sleeve. Then press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft. The step in the installer properly positions the oil seal sleeve on the rotor shaft.

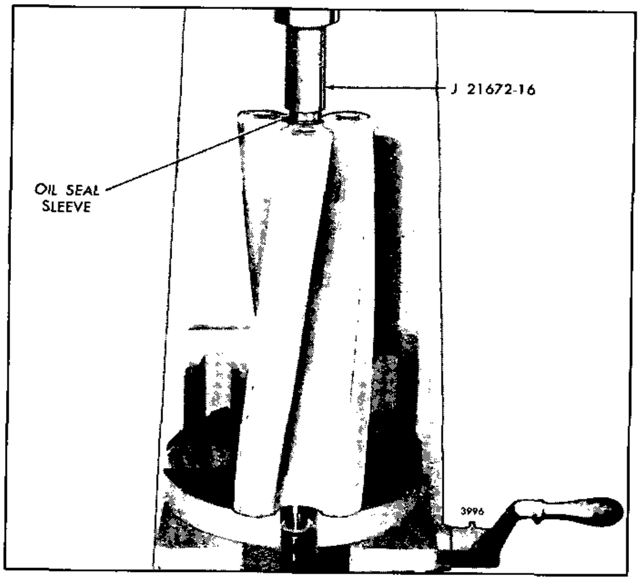


Fig. 12 – Installing Oil Seal Sleeve on Rotor Shaft (Former Blower)

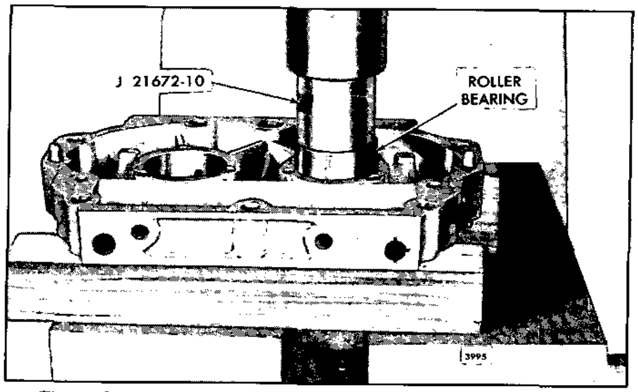


Fig. 13 – Installing Roller Bearing in Rear End Plate (Former Blower)

d. Install the remaining oil seal sleeve on the shaft of the second blower rotor.

e. Press a roller bearing inner race on the gear end of each blower rotor shaft with installer J 21672–16.

When installing a roller bearing inner race, note the tags previously placed on the bearings and races at the time of removal and install the bearing inner races, numbered end up, on the rotor shafts in their original positions. Do not intermix the races and bearings.

4. Install the roller bearings in the rear end plate as follows:

a. Support the rear end plate (inner face down) on two wood blocks on the bed of an arbor press as shown in Fig. 13.

The rear end plate may be identified by the bolt guide sleeve pressed into the right–hand bolt hole in the bottom of the end plate.

b. Lubricate the outside diameter of a roller bearing with engine oil. Note the tag previously placed on the bearing at the time of removal, then start the bearing, numbered end up, straight into the bearing bore in the end plate.

Be sure the bearing installed in the end plate will mate with its inner race on the rotor shaft.

c. Place the bearing installer J 21672–12 on top of the roller bearing, then press the bearing straight into and against the shoulder in the end plate.

d. Install the remaining roller bearing in the rear end plate in the same manner.

5. Install the blower rotors in the front end plate.

The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 20.

The front end plate should be attached to the front end of the blower housing first. The rear end plate is attached to the blower housing after the rotors are in place. The front end plate does not incorporate the bolt guide sleeve in the counterbored bolt hole in the bottom of the end plate. Install the blower rotors in the front end plate as follows:

a. Check the dowel pins. The dowel pins must project .380" from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

b. Hold the right–hand helix rotor in a vertical position, gear end up, with the omitted serration in the splines of the shaft facing to the right as shown in Fig. 20. Then start the end of the shaft straight into the oil seal in the right–hand shaft opening in the end plate as shown in Fig. 14 and lower it until the lobes of the rotor contact the end plate.

c. Position the left–hand helix rotor so the lobes of the rotors are in mesh and the omitted serration in the splines of the rotor shaft is facing in the same direction as the omitted serration in the right–hand helix rotor shaft. Then start the end of the shaft straight into the oil seal in the left–hand shaft opening in the end plate and lower it until the lobes contact the end plate.

6. Position the blower housing over the rotors, rear end of housing up, with the bottom of the housing facing toward the bottom of the end plate (Fig. 15). Lower the housing over the rotors and start it straight on the dowel pins in the front end plate, then push it down tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

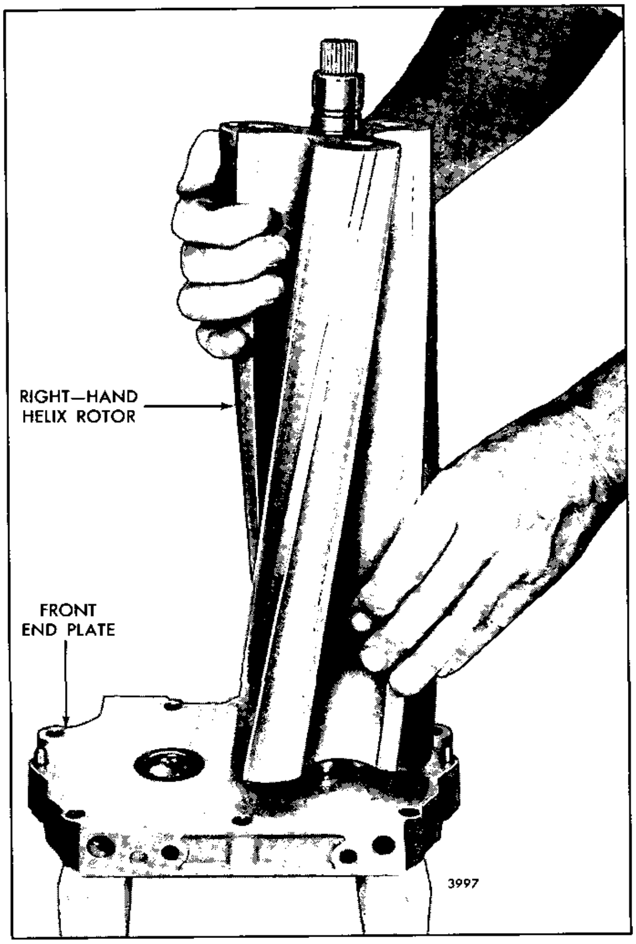


Fig. 14 – Installing Blower Rotor in Front End Plate

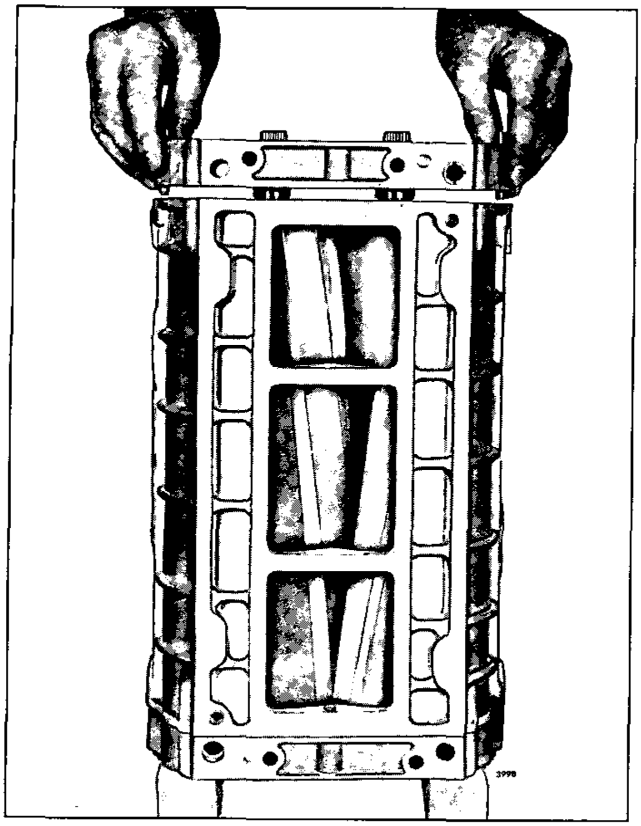


Fig. 15 – Installing Rear End Plate on Blower Rotors and Housing

*The blower housing is marked **REAR** near the top on the outside face of the housing and must be at the gear end of the rotors when assembled to the front end plate.*

7. Install the blower rear end plate on the rotor shafts and housing as follows:

   a. Check the dowel pins. The dowel pins must project .380″ from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

   b. Lubricate the inside diameter of the roller bearings with engine oil.

   c. Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the **TOP** side of the end plate facing the top side of the blower housing.

   d. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig. 15), then carefully work the dowel pins into the dowel pin holes in the housing and push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

   e. Install the 3/8″–16 socket head bolt in the counterbored bolt hole at the top of the end plate. Then install a 3/8″–16 hex head bolt with a flat washer in the center bolt hole at the bottom of the end plate.

   f. Place the bearing retainers on top of the bearings and he end plate, then install the retainer bolts. Tighten the bolts to 7–9 lb-ft (10–12 N·m) torque.

8. Reverse the blower housing, rotors and end plates on the wood blocks.

9. *Install a 3/8″–16 socket head bolt in the counterbored* bolt hole at the top of the end plate. Then install a 3/8″–16 hex head bolt with a flat washer in the center bolt hole at the bottom of the end plate.

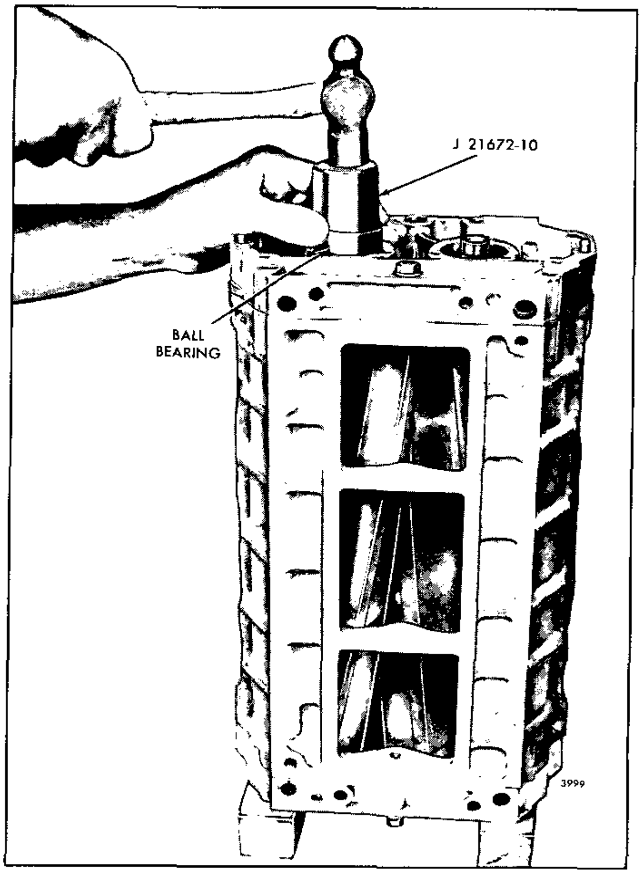


Fig. 16 – Installing Ball Bearings on Rotor Shafts and in Front End Plate (Former Blower)

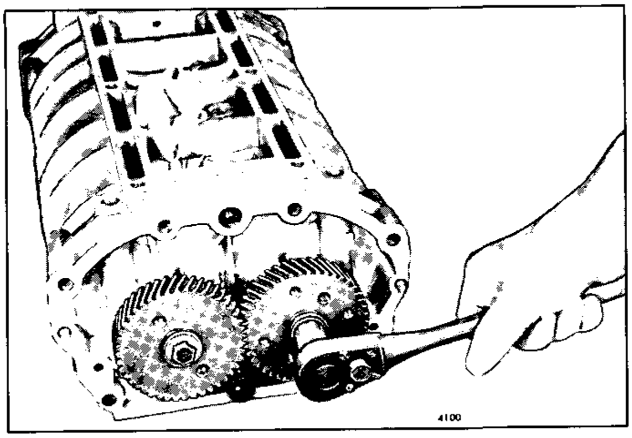


Fig. 17 – Installing Blower Rotor Gears

10. Install the ball bearings on the blower rotor shafts and in the front end plate as follows:

   a. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

   b. Place installer J 21672–10 on top of the bearing and tap the bearing straight on the shaft and into the front end plate as shown in Fig. 16.

   c. Install the second ball bearing on the remaining rotor shaft in the same manner.

   d. Place the bearing retainers on top of the bearings and the end plate, then install the retainer bolts. Tighten the bolts to 7–9 lb–ft (10–12 N·m) torque.

11. Place the blower assembly on a bench and make a preliminary check of the rotor–to–end plate and rotor–to–housing clearances at this time with a feeler gage as shown in Fig. 21. Refer to Fig. 19 for minimum blower clearances.

12. Install the blower rotor gears on the rotor shafts as follows:

   a. Place the blower assembly on the bench, with the top of the housing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

   b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing to the right (Fig. 20).

   c. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

   d. Lubricate the serrations of the rotor shafts with light engine oil.

   e. Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

   A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.

   f. Start the left–hand helix gear on the right–hand helix rotor and the right–hand helix gear on the left–hand helix rotor, with the omitted serrations in the rotor gears in line with the omitted serrations on the rotor shafts.

   g. Place the rotor gear pilots (43) on two 3/8″–24 x 2–3/4″ bolts, then thread a bolt into the end of each rotor shaft. Place a clean shop towel between the rotors and one between the rotor and the housing (Fig. 17) to prevent the gears from turning. Then draw the gears approximately half–way on the rotor shafts.

   h. Remove the two bolts and pilots that were used to draw the rotor gears half–way on the rotor shafts.

   i. Lubricate the threads of the rotor gear retaining bolts with engine oil.

   j. Place a pilot on each rotor gear retaining bolt with the counterbored side facing away from the bolt head.

   k. Thread the hex head bolt in the left–hand helix rotor shaft and the twelve point head bolt in the right–hand helix rotor shaft and draw the rotor gears into position tight against the shims and the bearing inner races as shown in Fig. 17. Tighten the bolts to 50–55 lb–ft (68–75 N·m) torque.

   l. Check the backlash between the rotor gears. The backlash should be .0005″ to .0025″ with new gears. Replace the gears if the backlash exceeds .0035″.

13. Install the 3/8″–24 x 2″ bolt with special flat washers in the right–hand helix rotor shaft at the front end of the blower. Tighten the bolt to 50–55 lb–ft (68–75 N·m) torque.

14. Place the bearing retainer nut lock washer over the end of the left–hand rotor shaft with the tang in the inner diameter of the washer in the notch in the shaft. Then thread the bearing lock nut on the shaft. Tighten the lock nut to 50–60 lb–ft (68–81 N·m) torque with spanner wrench J 21672–17.

15. Bend the tang of the lock washer over the notch of the bearing retainer nut.

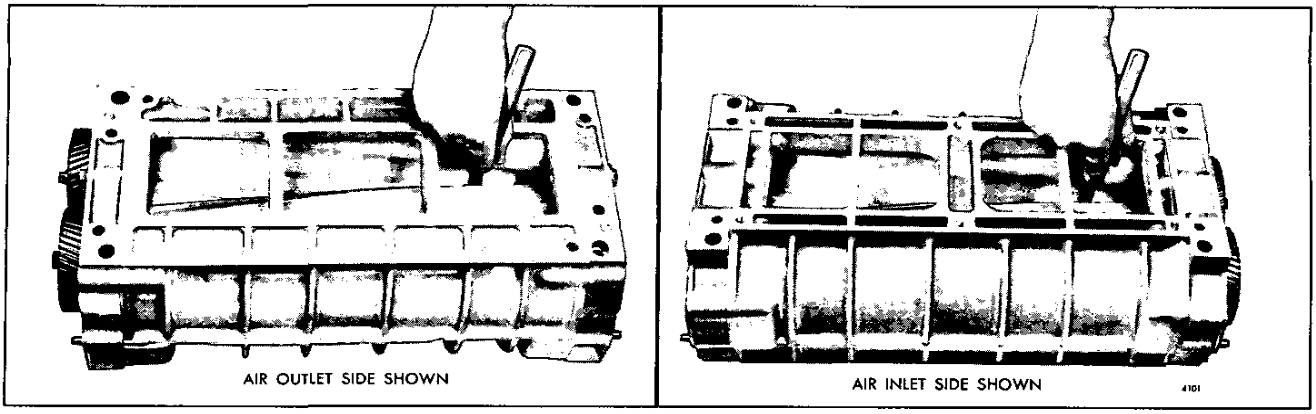
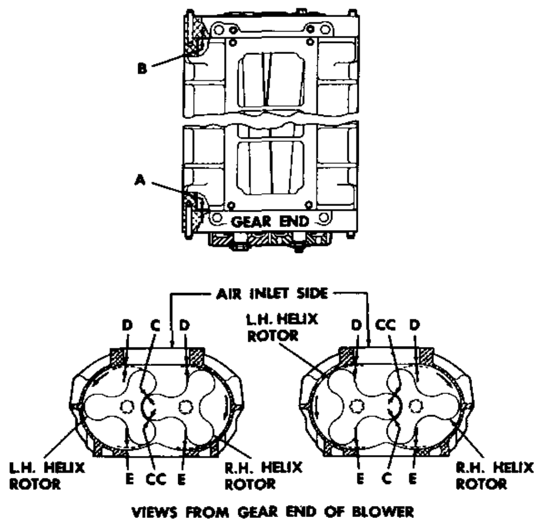


Fig. 18 – Measuring Clearance Between Blower Rotor Lobes



	A	B	C	CC	D	E
MIN.	.007"	.017"	.018"	.008"	.017"	.005"
* MIN.	.014"	.007"	.018"	.008"	.017"	.005"

11794

NOTE: Time rotors to dimensions on above chart for clearance between trailing side of R.H. Helix Rotor and leading side of L.H. Helix Rotor (cc) from both inlet and outlet side of blower.

*Use these clearances for blowers with ball bearings at the front and the roller bearings at the (rear) gear end.

Fig. 19 – Chart of Minimum Blower Clearances

Timing Blower Rotors

After the blower rotors and rotor gears are installed, the blower rotors must be timed.

1. The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

2. If the left–hand helix gear is moved out, the right–hand helix rotor will turn clockwise when viewed from the gear end. If the right–hand helix gear is moved out, the left–hand helix rotor will turn counterclockwise when viewed from the gear end. This positioning of the gear, to obtain the proper clearance between the rotor lobes, is known as blower timing.

3. Moving the gears *out* or *in* on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

4. The clearance between the rotor lobes may be checked with 1/2" wide feeler gages in the manner shown in Fig. 18. When measuring clearances of more than .005", laminated feeler gages that are made up of .002", .003" or .005" feeler stock are more practical and suitable than a single feeler gage. Clearances should be measured from both the inlet and outlet sides of the blower.

5. A specially designed feeler gage set J 1698–02 for the blower clearance operation is available. Time the rotors as follows:

   a. Time the rotors to pass an .008" feeler gage at the closest point between the *trailing* edge of the right–hand helix rotor and the *leading* edge of the left–hand helix rotor ("CC" clearance) measured from both the inlet and outlet sides as shown in Figs. 18 and 21.

   b. Then check the clearance between the *leading* edge of the right–hand helix rotor and the *trailing* edge of the left–hand helix rotor ("C" clearance) for the minimum clearance of .018". Rotor–to–rotor measurements should be taken 1" from each end and at the center of the blower.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown in Fig. 20 to produce the desired result. When more or less shims are

required, both gears must be removed from the rotors. Placing a .003" shim in back of a rotor gear will revolve the rotor .001".

7. Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

8. Determine the minimum clearances at points "A" and "B" shown in Fig. 19. Insert the feeler gages, as shown in Fig. 21, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

9. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side — 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

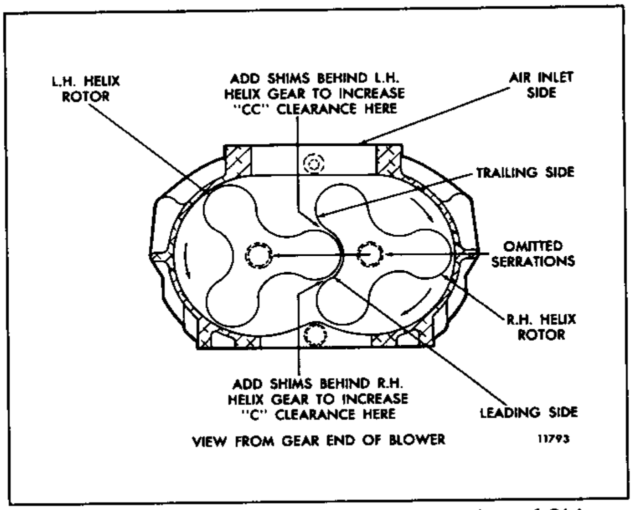


Fig. 20 – Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

Attach Accessories to Blower

On the former blowers, the drive hub is attached to the left–hand helix gear with four bolts. On the current blowers, a new drive hub is used with three bolt holes and utilizing two steel plates. The plates are bolted between the left–hand helix rotor drive gear and the drive hub to provide a flexible drive connection.

On former blowers, the right–hand helix rotor gear is separately interchangeable, but the current drive hub and attaching parts must be included to replace the left–hand helix rotor gear.

1. On the former blower, attach the blower drive hub to the left–hand helix rotor gear with four bolts. On the current blower, bolt two steel plates between the left–hand helix rotor drive gear and the drive hub. Tighten the bolts to 15–19 lb–ft (20–26 N·m) torque.

2. If removed, install a new blower drive hub oil seal (former blower) in the groove in the outside diameter of the drive hub.

3. Attach the blower drive support assembly to the blower assembly as follows:

   a. Affix a new gasket to the blower rear end plate. Then place the blower drive support assembly over the two dowel pins in the rear end plate and against the gasket.

   b. Attach the blower drive support assembly to the rear end plate with six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20–24 lb–ft (27–33 N·m) torque.

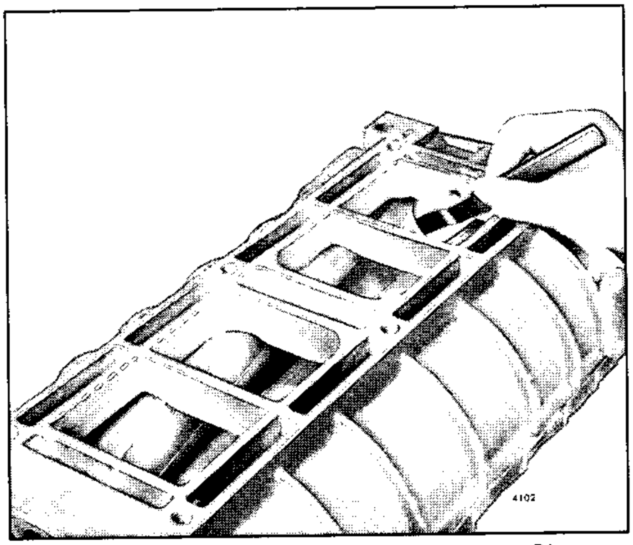


Fig. 21 – Measuring End Clearance Between Blower Rotors and End Plate

4. Attach the governor assembly to the blower assembly as follows:

   a. Affix a new gasket to the blower front end plate.

   b. Position the governor assembly in front of the blower, then start the weight shaft straight into the end of the rotor shaft. If necessary, rotate the weight shaft or rotor shaft to align the splines. Now push the governor assembly on the dowel pins in the end plate and against the gasket.

   c. Attach the governor to the front end plate with seven bolts and copper washers (two bolts inside and five outside). Tighten the bolts to 20–24 lb–ft (27–33 N·m) torque.

Install Blower

1. Affix a new governor housing gasket (83), Fig. 10, to the cylinder block.

2. Affix a new blower drive support housing gasket (84) to the cylinder block. Also affix a new gasket to the cylinder block rear end plate.

   NOTICE: Use Scotch Grip Rubber adhesive No. 1300, or equivalent, on the governor housing and blower drive support housing gaskets to prevent them from slipping when the blower assembly is lowered into position.

3. Place the blower housing–to–cylinder block seal ring in the groove in the top of the cylinder block.

4. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at the side of each cylinder head.

5. Thread eyebolts in two diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and a chain hoist to the eyebolts as shown in Fig. 4.

6. Lift the blower assembly at a slight angle and position it over the top of the cylinder block. Then lower the assembly on the cylinder block and mesh the blower drive gear with the camshaft gear.

7. Install two 7/16"–14 x 7–1/2" bolts and special washers in each blower end plate. Tighten the bolts to 55–60 lb–ft (75–81 N·m) torque.

8. Install the two 7/16"–14 x 7/8" governor housing–to–cylinder block bolts and copper washers. Tighten the bolts to 46–50 lb–ft (62–68 N·m) torque.

9. Install the five blower drive support housing–to–engine end plate bolts, lock washers and one plain washer. Tighten the bolts to 20–24 lb–ft (27–33 N·m) torque.

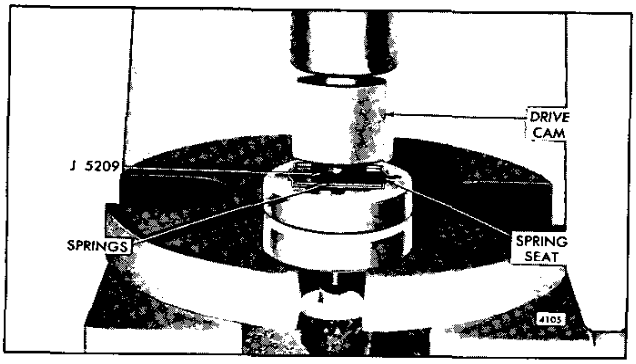


Fig. 22 – Inserting Blower Drive Cam in Springs

10. If disassembled, install the springs and blower drive cam in the two blower drive coupling supports as follows:

    a. Place the drive spring supports on a bench. Then place the drive spring seats inside the support.

    b. Lubricate the springs with engine oil. Then place the spring packs, consisting of 15 leaves per pack, in between the spring seats as shown in Fig. 22.

    c. Place the second drive spring support on top of the first drive spring support, then install the spring seats and spring packs in the second support as outlined in Steps "a" and "b" above.

    d. Place the two drive spring supports, with springs, over a small opening in the bed of an arbor press so the spring seats and the ends of the spring packs will rest on the bed of the arbor press.

    e. Place the blower drive cam, the protruding end of the cam down, over the end of the installer J 5209. Insert the tapered end of the installer in between the spring packs and under the ram of the press, then press the cam into place between the spring packs as shown in Fig. 22. Catch the installer by hand after it passes through the spring packs.

11. Attach the blower drive coupling supports to the blower drive gear as follows:

    a. Insert the blower drive coupling supports through the opening in the rear face of the flywheel housing, with the protruding end of the drive cam facing the drive shaft (Fig. 1).

    b. Align the bolt holes in the supports with the holes in the blower drive gear, then thread two bolts with flat washers in two diametrically opposite holes, finger tight only. Install the two remaining bolts finger tight only.

    c. Insert the blower drive shaft, flat end first, through the blower drive cam and into the blower drive hub. Then tighten the two bolts with the flat washers to 8–10 lb–ft (11–14 N·m) torque.

    d. Check the blower drive shaft for alignment and freeness by sliding the shaft in and out of the splines in the drive hub and cam. If the drive shaft binds, loosen the two bolts with flat washers and move the blower drive support coupling slightly and retighten the bolts.

    e. Remove the two bolts without the flat washers. Place the blower drive shaft retainer against the

end of the blower drive support, then install the two bolts and tighten them to 8–10 lb–ft (11–14 N·m) torque.

12. Affix a new gasket to the blower drive gear hole cover, then place the cover in position against the flywheel housing and install the five bolts and lock washers. Tighten the 5/16"–18 bolts to 13–17 lb–ft (18–23 N·m) torque and the 3/8"–16 bolt to 20–24 lb–ft (27–33 N·m) torque.

13. Slide the fuel rod cover tube hoses up on the cover tubes in the governor housing and tighten the hose clamps.

14. Install the governor fuel rods and connect them to the governor and injector rack control levers.

15. Place the governor cover on the governor housing and secure it in place with eight screws and lock washers.

16. Connect the fuel oil supply line to the fuel oil pump and the fuel oil filter.

17. Connect the fuel oil supply and return lines to the fuel manifold fittings in the cylinder heads.

18. Place the water by–pass tube with seal rings and flanges in between the two thermostat housings and secure it in place with four bolts and lock washers. Tighten the bolts to 7–9 lb–ft (10–12 N·m) torque.

19. Connect the blower housing breather tube and hose to the breather housing with a hose clamp, then attach the tube clamp at the lower end of the tube to one of the water pump attaching bolts.

20. Attach the air compressor (if used) to the engine flywheel housing as follows:

    a. Affix a new gasket to the bolting flange of the air compressor.

    b. Install the air compressor drive coupling in the drive plate attached to the rear face of the camshaft gear.

    c. Place the air compressor in position at the rear of the flywheel housing and guide the teeth on the drive coupling into the teeth in the drive plate on the air compressor, then push the air compressor against the flywheel housing. If necessary, rotate the crankshaft to align the teeth of the drive coupling and the drive plate.

    d. Install the four bolts and lock washers and tighten them to 71–75 lb–ft (96–102 N·m) torque.

    e. Connect the water inlet and outlet tubes to the air compressor. Then connect the oil supply line to the air compressor and the cylinder block.

21. If removed, attach the battery–charging generator mounting bracket to the top of the governor housing with four bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

22. Attach the battery–charging generator to the mounting bracket. Install the generator drive belts, then tighten the generator mounting bolts and adjust the drive belt tension.

23. Use new gaskets and install a valve rocker cover on each cylinder head.

24. Attach a valve rocker cover breather tube to each rocker cover with a hose clamp, then secure the breather tube clamp at the lower end of each tube to the flywheel housing.

25. Place the blower screen and gasket assembly in position on top of the blower, with the screen side of the assembly toward the blower. Then place the air inlet adaptor on the blower screen. Install the six bolts and lock washers and tighten them to 16–20 lb–ft (22–27 N·m) torque.

26. Affix a new gasket to the top of the air inlet adaptor, then place the air shutdown housing on top of the gasket. Install the six bolts and lock washers and tighten them to 16–20 lb–ft (22–27 N·m) torque.

27. Connect the throttle control rods to the governor levers.

28. Attach any other accessories that were removed from the engine.

29. Adjust the governor and injector rack control levers as outlined in Section 14. Check for and repair any coolant or oil leaks detected when performing the tune–up.

TURBOCHARGER (AIRESEARCH)

TE0675 TURBOCHARGER

The TE0675 turbocharger (Figs. 1 and 2) is designed to increase engine efficiency and power output. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a radial inward flow turbine wheel and shaft, a centrifugal compressor wheel, and a center housing which serves to support the rotating assembly, bearings, seals, turbine housing and compressor housing. The center housing has connections for oil inlet and outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of the turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by retaining rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and thrust collar, thrust bearing, piston ring(s) and thrust spacer.

The oil is sealed off from the compressor and the turbine by seal arrangements at both ends of the center housing. Oil drains from the center housing by gravity.

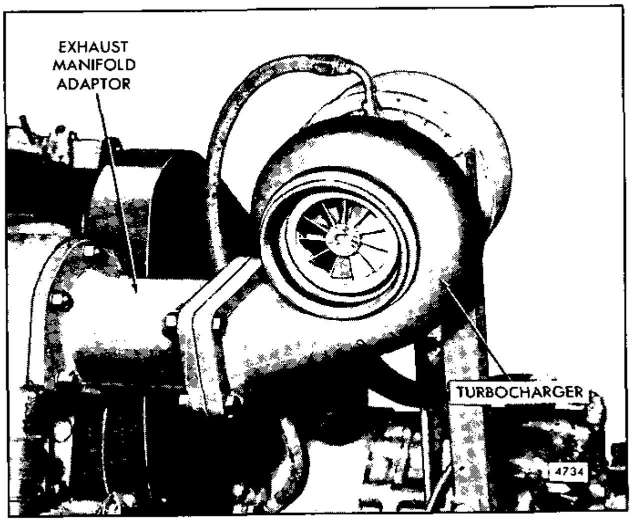


Fig. 1 – Turbocharger Mounting

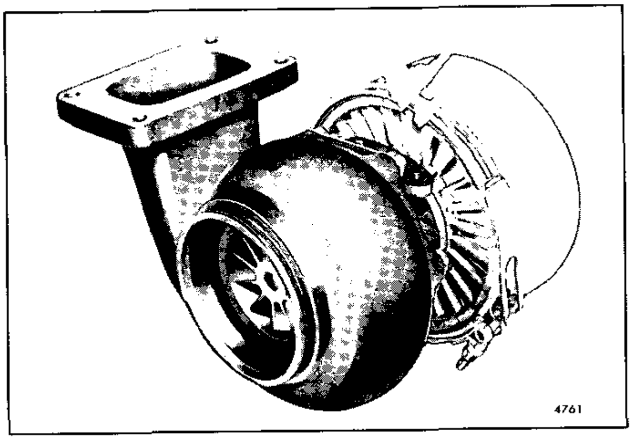


Fig. 2 – Turbocharger Assembly

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially–located turbocharger exhaust gas outlet. The turbine housing is bolted to the turbine end of the center housing, thus providing a compact and vibration free assembly.

The compressor housing which encloses the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The compressor housing is bolted to the compressor end of the center housing backplate assembly with a "V" band coupling.

Operation

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 3). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws the ambient air into the compressor housing, compresses it and delivers it to the engine blower.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the engine power output increases or decreases, the turbocharger responds to the engine's demand to deliver the required amount of air under all conditions.

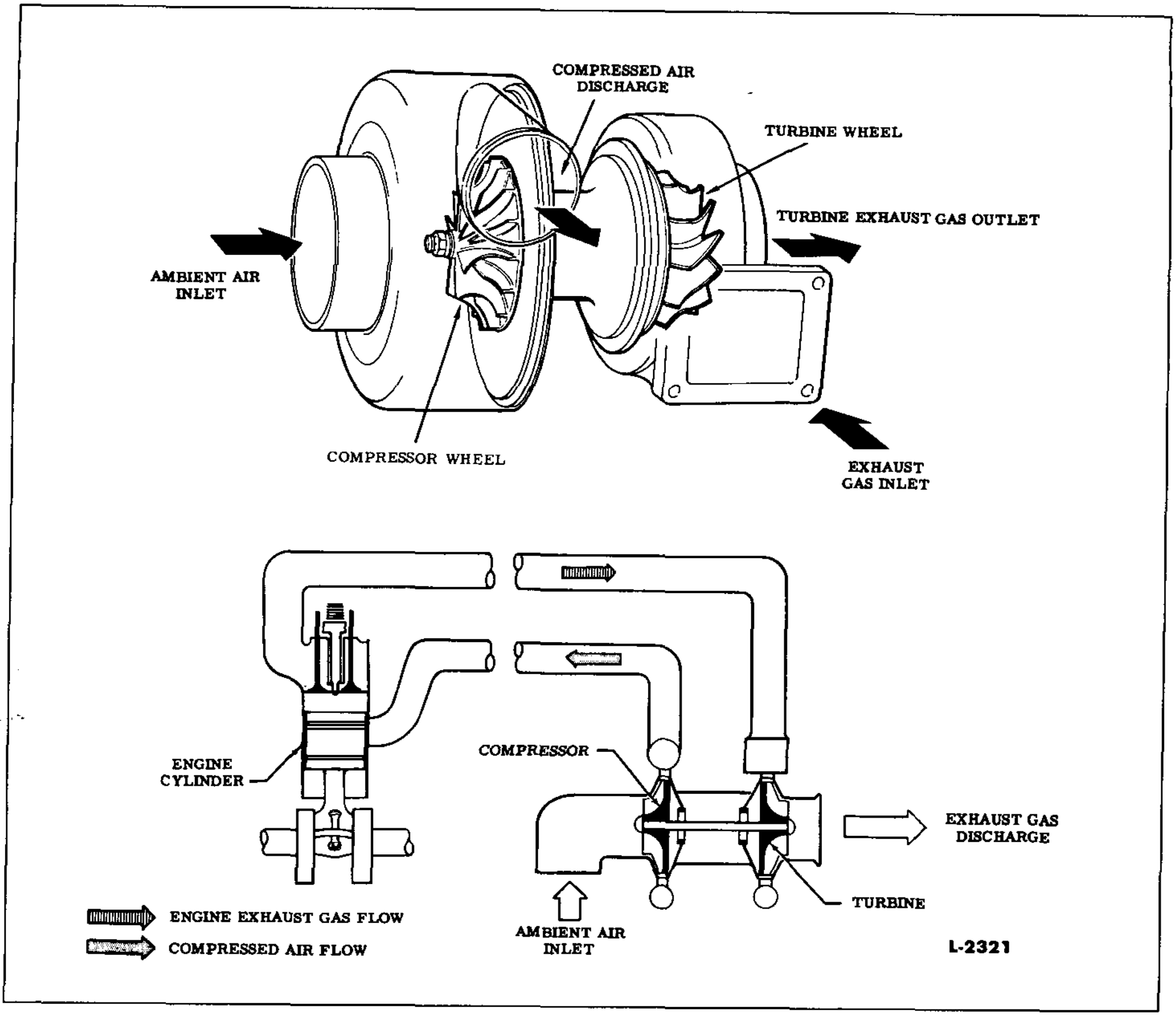


Fig. 3 – Schematic Flow Diagram

Certain engines are equipped with an intercooler to reduce the temperature of the discharge air from the turbocharger before it enters the engine blower (Section 3.5.2).

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing and backplate. The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the side of the cylinder block.

Minimum oil flow to the turbocharger with the engine at idle speed is achieved at 10 psi (69 kPa) with an oil temperature of 200°F (93°C).

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger.*

NOTICE: Failure to perform the prelubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Periodic Inspection

CAUTION: To avoid personal injury, a turbocharger compressor inlet shield, J 26554-A, should be installed anytime the engine is operated with the air inlet piping removed (Fig. 4). The shield helps keep foreign objects from entering the turbocharger and prevents a service technician from touching the moving impeller. The use of this shield *does not* preclude any other saftey practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

NOTICE: Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Troubleshooting Charts* (Fig. 5). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTICE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt and dust buildup.

For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 5. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine. *Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.*

Check for signs of oil leaking from the turbocharger housings.

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 5.

Oil pull–over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pullover.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 5.

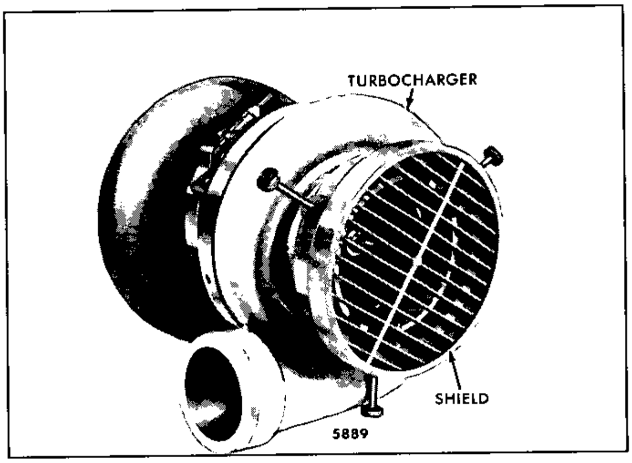


Fig. 4 – Inlet Shield (J 26554–A)

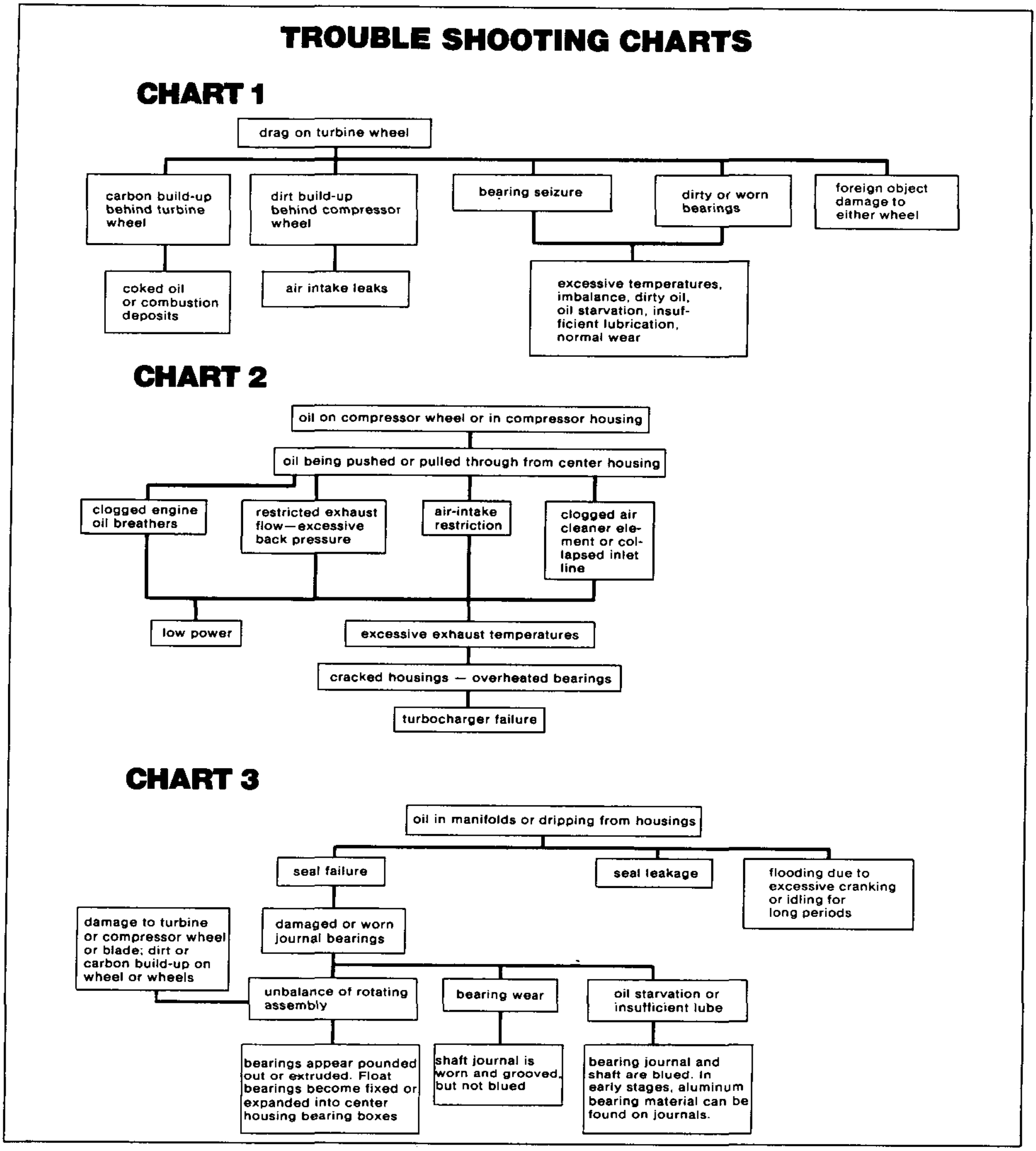


Fig. 5 – Inspection Checks for Turbocharger

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal:

1. A worn or defective oil seal, which must be replaced.
2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.
3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.
2. Be certain that the turbocharger oil drain line is unrestricted.
3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.
4. Remove air intake ducting. Inspect inside of ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.
5. Remove the compressor housing from the turbocharger.
6. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.
7. Spray the backplate annulus with a light coating of "Spot–Check" developer type SKD–MF, or equivalent.
8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.
9. Warm up the engine to normal operating temperature.
10. Operate the engine at no load at the governor limited high speed for approximately five minutes.
11. Return the engine to low idle and then stop it.
12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the "Spot–Check" developer on the backplate annulus. This surface should be completely free of oil streaks after the test.
13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Refer to Fig. 6 and remove the turbocharger support bracket.
2. Disconnect the oil supply line and the oil drain line from the turbocharger.
3. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entrance of foreign material.
4. Loosen the two hose clamps securing the cover hose to the turbocharger and the air inlet tube and slide the cover hose down over the inlet tube.

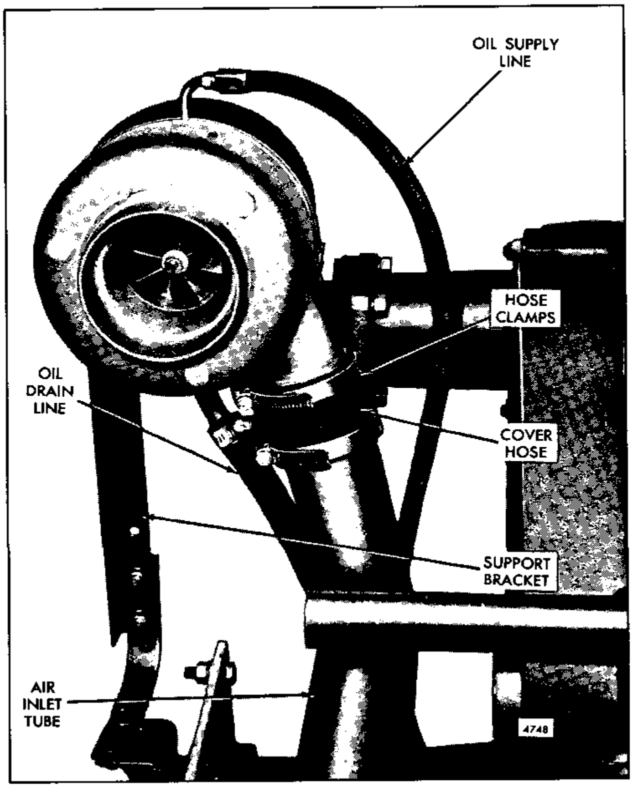


Fig. 6 – Turbocharger Support Bracket, Oil Lines and Air Inlet Tube

5. Remove the four bolts, nuts and lock washers securing the turbocharger to the exhaust manifold adaptor and remove the turbocharger and gasket. Refer to Fig. 1.

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

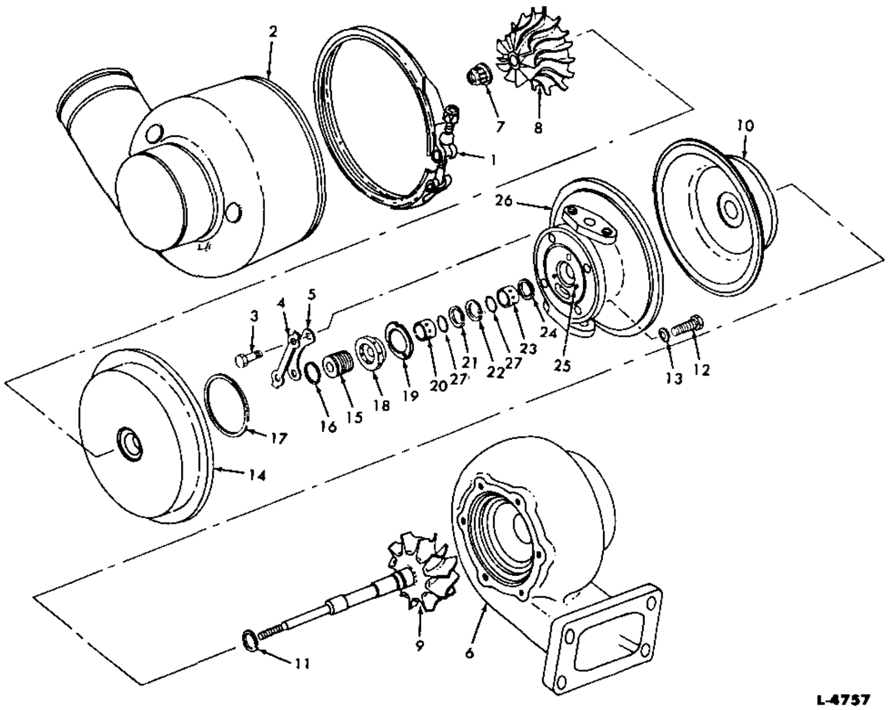
NOTICE: Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

1. Loosen the "V" band coupling (1) securing the compressor housing (2) to the backplate assembly (14) and remove the compressor housing and "V" band.

NOTICE: Exercise care when removing the center and turbine housings to prevent damage to the compressor or turbine wheel.

2. Bend down the ends of the lockplates and remove the eight bolts (3) securing the four lockplates (4) and turbine housing clamps (5) to the center housing (26) and turbine housing (6). Remove the turbine housing from the center housing. Tap the housing with a soft headed hammer if force is needed for removal.

3. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut (7) from the shaft.



1.	Coupling—"V" Band	8.	Wheel—Compressor	14.	Backplate Assembly	21.	Ring—Retaining
2.	Housing—Compressor	9.	Shaft—Turbine Wheel Assembly	15.	Spacer—Thrust	22.	Ring—Retaining
3.	Bolt			16.	Ring—Piston	23.	Bearing
4.	Lockplate	10.	Shroud—Turbine Wheel	17.	Ring—Seal	24.	Ring—Retaining
5.	Clamp—Turbine Housing	11.	Ring—Piston	18.	Collar—Thrust	25.	Pin—Groove
6.	Housing—Turbine	12.	Screw	19.	Bearing—Inboard Thrust	26.	Housing—Center
7.	Nut—Self-Locking	13.	Lockplate	20.	Bearing	27.	Spacer

Fig. 7 – Model TE0675 Turbocharger Details and Relative Location of Parts

NOTICE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Place the center housing and rotating assembly in a oven, furnace or hot oil bath that has been preheated to 350–375°F (177–190°C) for no longer than ten minutes.

5. Press the compressor wheel (8) from the wheel shaft assembly (9).

6. Withdraw the wheel shaft assembly (9) and wheel shroud (10) from the center housing. The wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.

7. Remove the piston seal (11) from the wheel shaft assembly (9).

8. Bend down the lock tabs and remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (26) and remove the backplate assembly. Tap the backplate lightly to remove it from the center housing recess.

9. Remove and discard the seal ring (17) from the groove in the center housing.

10. Remove the thrust spacer (15) and piston ring(s) (16) from the backplate assembly. Discard the piston ring(s).

11. Remove the thrust collar (18), inboard thrust bearing (19), bearing (20), spacer (27) if used, and retaining ring (21) from the center housing. Discard the bearing and retaining ring.

12. Remove the retaining ring (22), spacer (27) if used, bearing (23) and retaining ring (24) from the center housing. Discard the retaining ring and bearing.

Cleaning

Before cleaning, inspect all of the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all of the parts in a non–caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel for signs of rubbing. For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished. Use a silicone carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

It is recommended that piston ring(s), thrust washers, bearings, bearing washers and retaining rings be replaced at time of disassembly.

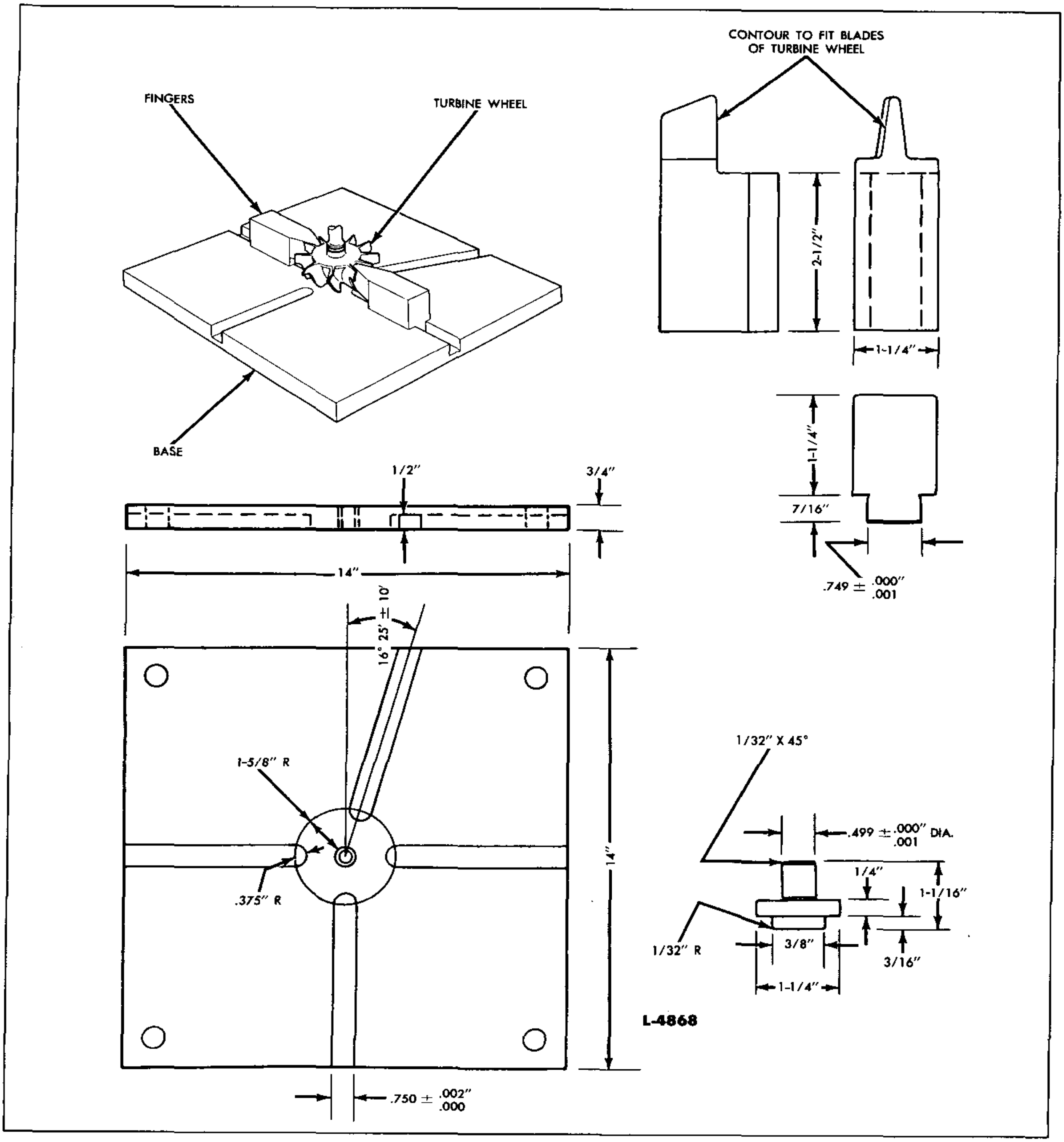


Fig. 8 – Turbocharger Holding Fixture

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Fig. 7 for parts orientation and proceed as follows:

1. Lubricate the new bearings (20 and 23) with clean engine oil.
2. Install a new retaining ring (24), bearing (23), spacer (27) and retaining ring (22) in the turbine housing end of the center housing (26).
3. Install a new retaining ring (21), spacer (27) and bearing (20) in the center housing.
4. Install a new piston ring(s) (16) on the thrust spacer (15) and gently insert the spacer into the backplate assembly (14).

   The current thrust spacer has two grooves. When replacing the former one groove spacer with the two groove spacer, be sure and include two piston rings.

   NOTICE: Do not force the piston rings into place.

5. Position the inboard thrust bearing (19) flat against the center housing with the hole and cut-outs in the bearing in alignment with the pins (25) in the center housing.
6. Install the thrust collar (18) snugly against the thrust bearing (19). Lubricate the thrust collar and bearing with clean engine oil.
7. Install a new seal ring (17) in the groove in the backplate assembly (14).
8. Align the oil feed holes in the center housing (26) and the backplate assembly and install the backplate, using four bolts (12) and new lockplates (13). Tighten the bolts to 75-90 **lb-in** (8–10 N·m) torque and bend the lockplate tangs up against the side of the bolt heads.
9. Install a new piston seal (11) on the wheel shaft assembly (9).
10. Position the wheel shroud (10) against the center housing (26) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing.

    NOTICE: Be careful not to scuff or scratch the bearings when installing the shaft. Do not use force to compress the piston ring into place. A gentle rocking and pushing action will allow the piston ring to seat and the shaft to bottom. A thin tool may be used as an aid in compressing the piston ring is difficulty is encountered.

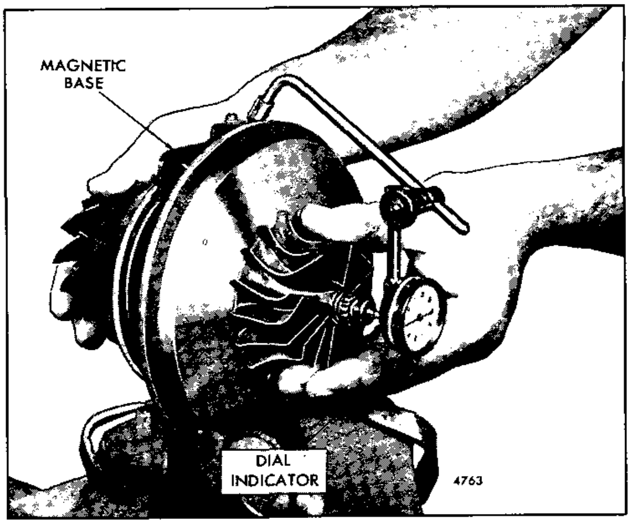


Fig. 9 – Checking Bearing Axial End Play

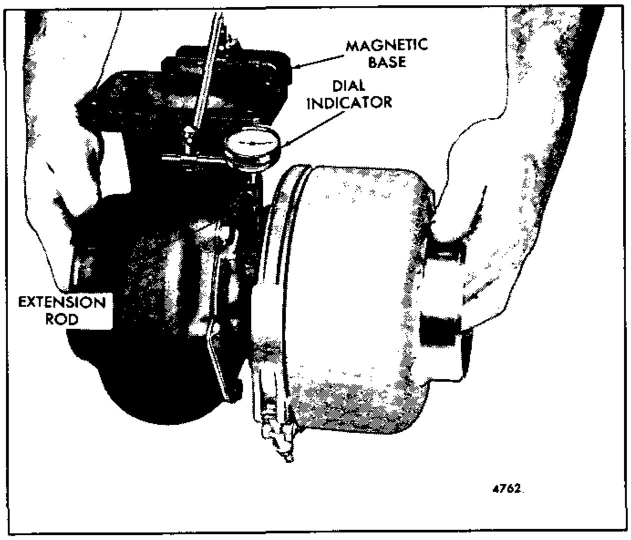


Fig. 10 – Checking Shaft Radial Movement

11. Heat the compressor wheel in an oven or hot oil bath to 325–375°F (163–190°C) for no more than ten minutes.
12. Position the turbine wheel (9) of the center housing assembly in the holding fixture (Fig. 8).
13. Position the compressor wheel over the shaft and install the wheel retaining nut. Tighten the nut to 120 **lb-in** (14 N·m) torque. After the compressor wheel has cooled to room temperature, remove the retaining nut.
14. Check the face of the retaining nut and the wheel face to make sure they are smooth and clean. Lightly oil the shaft threads and washer face and reinstall the nut. Tighten the nut to 18–20 **lb-in** (2 N·m) torque. Continue to tighten until the shaft increases in length

.008"–.009". Tighten the retaining nut in such a manner so as not to impose a bending load on the shaft.

15. Check the bearing axial end play:

    a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 9.

    b. Fasten the dial indicator and magnetic base (J 7872) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side.

    c. *Move the shaft axially back and forth by hand.* The total indicator reading (thrust float) should be between .004" and .007". If the dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing (6) as marked at disassembly against the center housing (26) and secure it in place with four clamps (5), four lockplates (4) and eight bolts (3). Tighten the bolts to 160–190 **lb–in** (18–22 N·m) torque. Bend the lockplate tabs up against the flat on the bolt heads.

17. Position the compressor housing (2) against the backplate assembly (14) and secure it in place with the "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut on *the coupling to 30–45* **lb–in** *(3–5 N·m) torque.*

18. After assembly, push the rotating assembly as far as possible from the turbine end. Then, rotate the assembly and check for bind. Push the rotating assembly in the opposite direction and repeat the check.

19. Check the shaft radial movement:

    a. Position the magnetic base J 7872–2 with the swivel adaptor J 7872–3 on the flat surface of the turbine housing inlet flange as shown in Fig. 10.

    b. Fasten the dial indicator extension rod J 7057 to the dial indicator J 8001–3 and attach the dial indicator to the swivel adaptor.

    c. Insert the extension rod into the oil drain tube mounting pad opening so that it is against the wheel shaft and is perpendicular to the shaft.

    NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

    d. Grasp each end of the rotating assembly and, *applying equal pressure at each end, move the* rotating shaft first toward and then away from *the dial indicator, creating a transverse* movement in the shaft. The dial indicator displacement should be between .003" and .007". If the displacement does not fall within the specified limits, disassemble and repair or replace the rotating assembly.

20. If it is to be stored, lubricate the turbocharger internally and install protective covers on all openings.

21. Stamp the letter "R" in the lower left–hand corner of the name plate to identify that the turbocharger has been reworked.

Install Turbocharger

If a turbocharger is to be installed on a new or overhauled engine, operate the engine for approximately one hour *before* the turbocharger is installed. This must be done to ensure that no foreign material is carried from the engine into the turbocharger lubrication system.

1. Position the turbocharger, using a new gasket, against the exhaust manifold adaptor and secure it in place with four bolts, lock washers and nuts (Fig. 1).

2. Slide the cover hose (Fig. 5) over the end of the turbocharger air outlet opening and tighten the two hose clamps.

3. Install the turbocharger support bracket.

4. Install the oil drain line from the opening in the bottom side of the center housing (Fig. 5) to the cylinder block.

5. Attach the oil inlet line at the cylinder block.

6. After installing a rebuilt or new turbocharger, it is very important that all of the moving parts of the turbocharger center housing be lubricated as follows:

    a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 3).

    b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

    c. Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

    d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving A good parts. indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 69 kPa *at idle speed*).

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

7. Check all ducts and gaskets for leaks.

8. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TO4B AND TV61 TURBOCHARGERS

The turbocharger (Figs. 11 and 12) is designed to increase engine efficiency and power output. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a turbine wheel and shaft, a compressor wheel, a center housing which serves to support the rotating assembly, bearings, seals, a turbine housing and a compressor housing. The center housing has connections for oil inlet and outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of the turbine wheel and shaft assembly, piston ring, thrust collar, thrust bearing, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by retaining rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and thrust bearing, piston ring and thrust collar.

The oil is sealed off from the compressor and the turbine by seal arrangements at both ends of the center housing. Oil drains from the center housing by gravity.

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially–located turbocharger exhaust gas outlet. The TO4B turbine housing is bolted to the turbine end of the center housing and the TV61 turbine housing is secured to the center housing with a "V" band coupling.

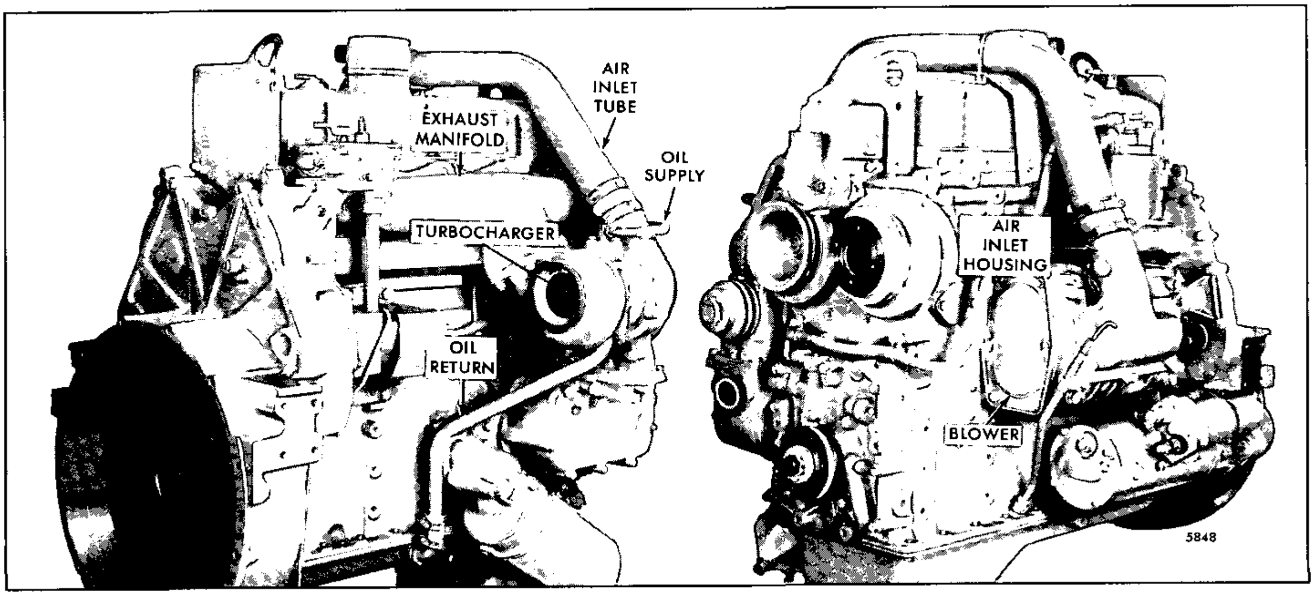


Fig. 11 – TO4B Turbocharger Mounting (In–Line Engine)

The compressor housing, which encloses the compressor wheel, provides an ambient air inlet and a compressor air discharge outlet. The compressor housing is bolted to the backplate assembly. The TO4B backplate assembly is bolted to the compressor end of the center housing. The TV61 backplate assembly is secured to the compressor end of the center housing with a "V" band coupling.

Operation

The TO4B turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold (Fig. 11). The TV61 turbocharger is mounted between the air inlet housing and the air outlet tube adaptor. The air inlet housing is mounted on the blower. The air outlet tubes are clamped to the exhaust outlet flange of each engine exhaust manifold and the air outlet tube adaptor (Fig. 12).

After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 13). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws the ambient air into the compressor housing, compresses the air and delivers it through the blower to the engine cylinders.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the power output of the engine increases, the flow of exhaust gases increases and the speed and output of the rotating assembly increases proportionately, delivering more air to the engine blower.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust collar and thrust bearing (Fig. 14). The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger*.

NOTICE: Failure to perform the pre-lubrication procedure may result in premature bearing damage due to "oil lag" or lack of lubrication.

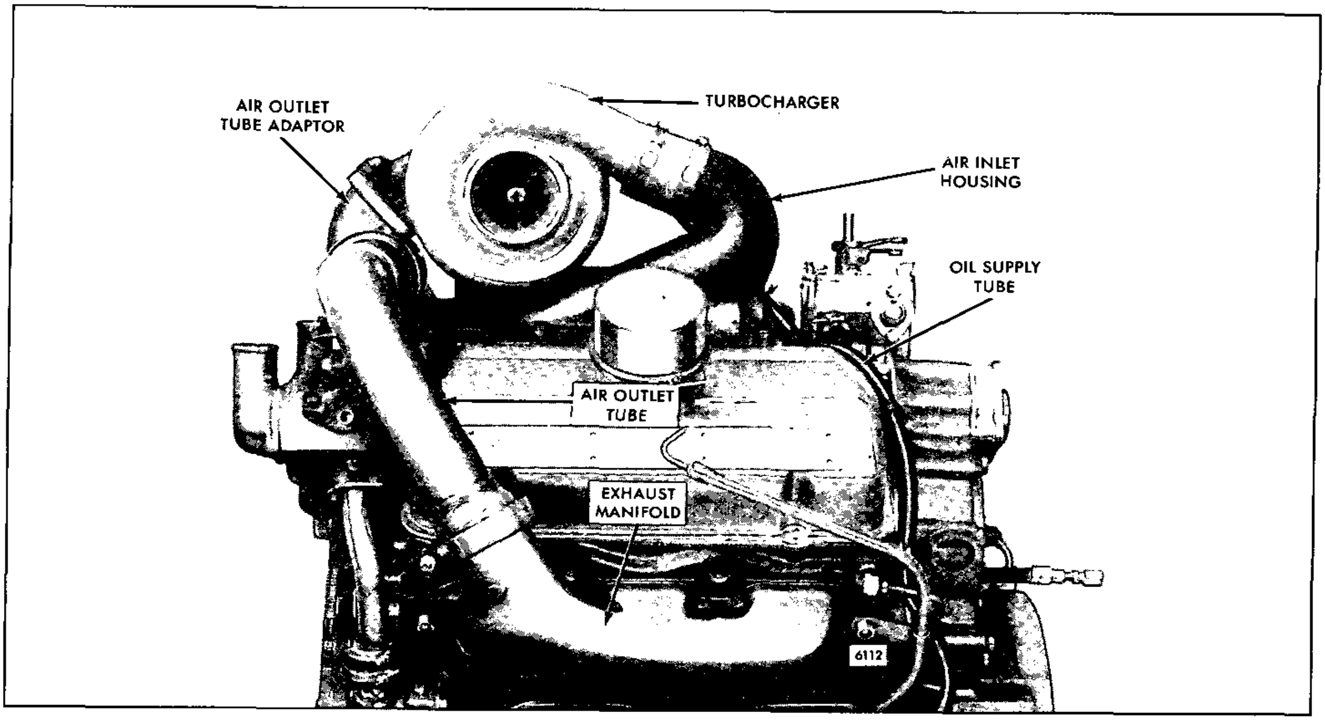


Fig. 12 – TV61 Turbocharger Mounting (6V Engine)

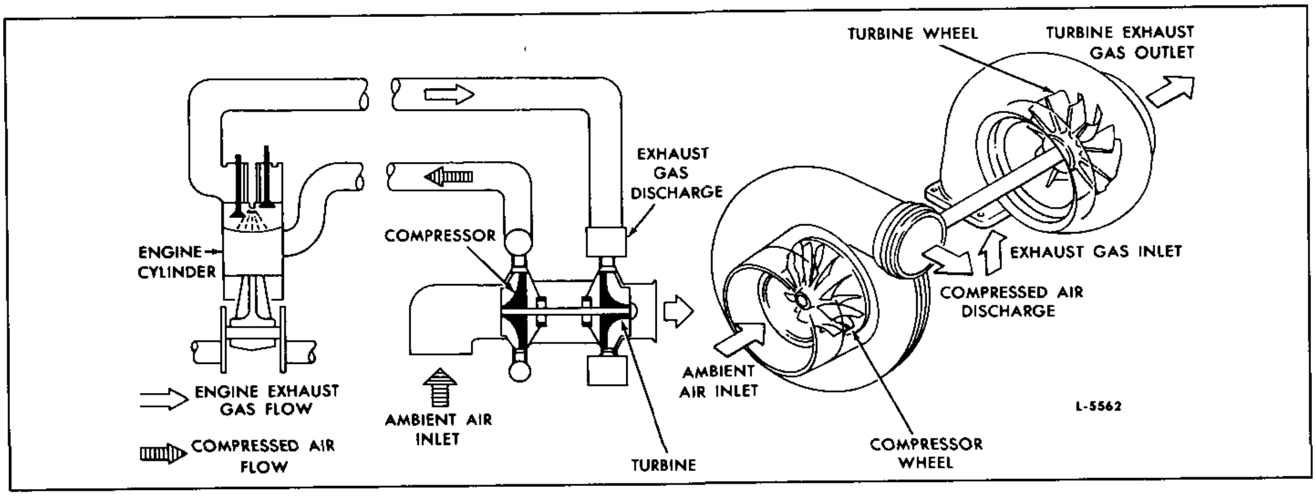


Fig. 13 – Schematic Air Flow Diagram

Periodic Inspection

NOTICE: A turbocharger compressor inlet shield, J 26554–A, is available for use anytime the engine is operated with the air inlet piping removed (Fig. 4). The shield helps to prevent foreign objects entering the turbocharger and prevents a service technician from touching the moving impeller. The use of this shield *does not* preclude any other safety practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

NOTICE: Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Troubleshooting Charts* (Fig. 5). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTICE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt and dust buildup.

For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 5. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine. *Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.*

Check for signs of oil leaking from the turbocharger housings.

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in

these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 5.

Oil pull-over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pull-over.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 5.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal:

1. A worn or defective oil seal which must be replaced.
2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.
3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate.

If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.
2. Be certain that the turbocharger oil drain line is unrestricted.

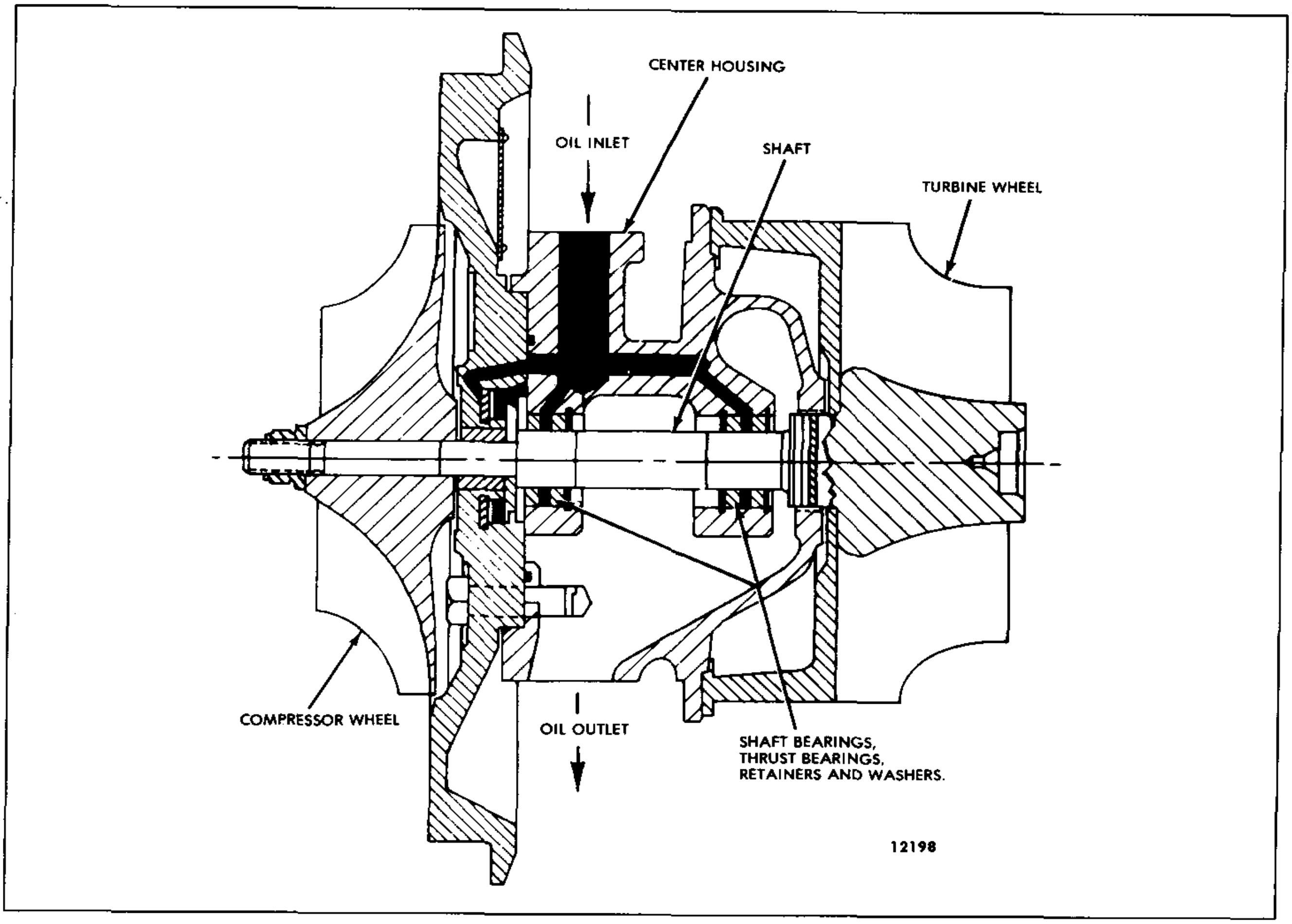


Fig. 14 – Turbocharger Oil Flow Diagram

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove the air intake ducting. Inspect the inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of *Spot–Check* developer type SKD–MF, or equivalent.

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm up the engine to normal operating temperature.

10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the *Spot–Check* developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Remove the TO4B turbocharger support bracket.

2. Disconnect the oil supply line and the oil drain line from the turbocharger.

3. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entrance of foreign material.

4. Loosen the two hose clamps securing the cover hose to the turbocharger and the air inlet tube and slide the cover hose down over the inlet tube.

5. Remove the four bolts, nuts and lock washers securing the turbocharger to the exhaust manifold adaptor or exhaust outlet flange and remove the turbocharger and gasket.

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembling and proceed as follows:

NOTICE: Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly o assure reassembly in the same relative position.

TO4B Turbocharger – Fig. 15.

1. Bend the lock tabs of the lock plates down and remove the bolts which hold the lockplates and clamps securing the compressor housing and turbine housing.

   NOTICE: Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels. Tap the housing with a soft hammer if force is needed for removal.

2. Position the turbine wheel of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut from the shaft. If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

   NOTICE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

3. Lift the compressor wheel off of the turbine wheel shaft assembly.

4. Invert the center housing and turbine wheel assembly and remove the turbine wheel assembly (with piston ring) from the center housing. Remove the piston ring from the wheel assembly.

5. Bend the lock tabs down and remove the bolts and lockplates securing the backplate assembly to the center housing. Remove the backplate assembly.

   NOTICE: Tap the backplate lightly to remove it from the center housing recess.

6. Do not disassemble the backplate assembly. Also, do not remove the pins from the center housing, unless it is necessary to replace the pins.

7. Remove and discard the seal ring from the groove in the center housing.

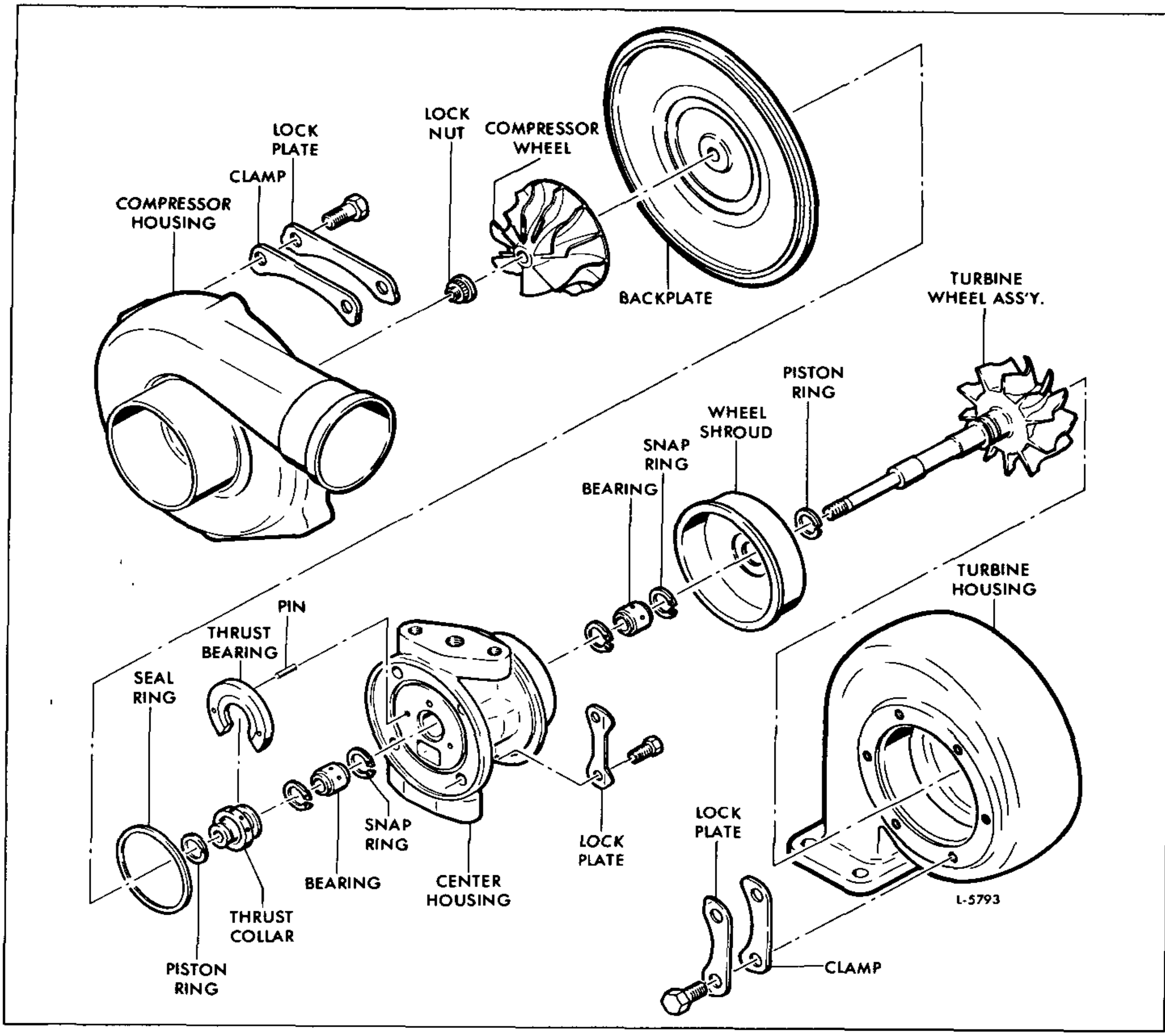


Fig. 15 – TO4B Turbocharger Details and Relative Location of Parts

8. Remove the thrust bearing and piston ring from the backplate assembly. Discard the piston ring.

9. Remove the thrust collar, bearing and snap ring from the center housing. Discard the bearing and snap ring.

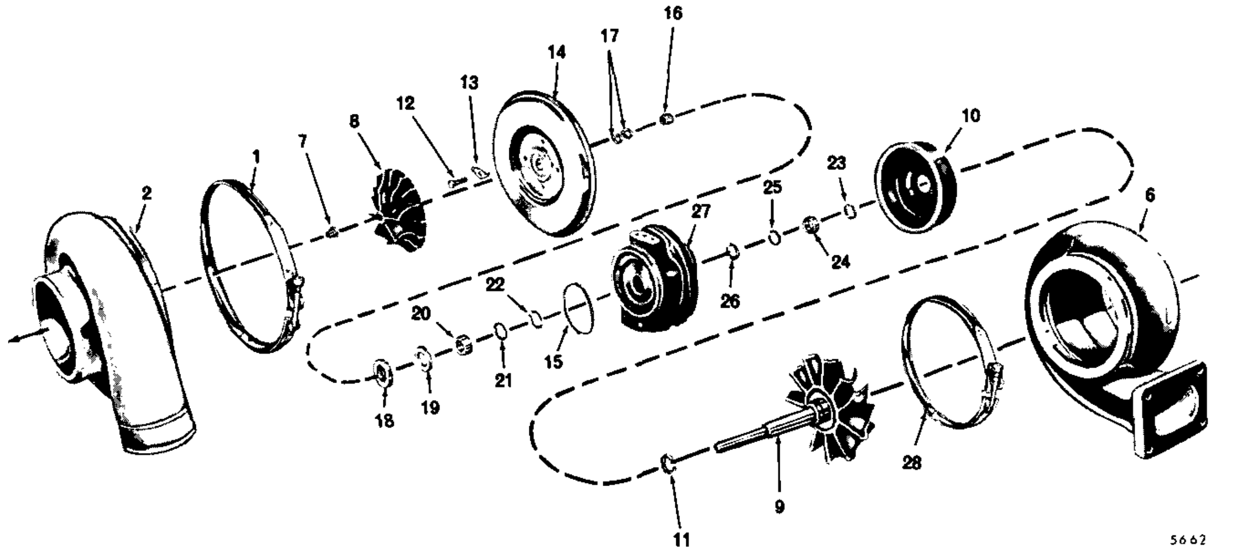
10. Remove the snap ring, bearing and snap ring from the opposite end of the center housing. Discard the snap rings and bearing.

TV61 Turbocharger – Fig. 16.

1. Loosen the "V" band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and "V" band.

   NOTICE: Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen the "V" band coupling securing the turbine housing to the center housing. Remove the turbine housing from the center housing. Tap the housing with a soft hammer if force is needed for removal.



1.	Coupling—"V" Band	10.	Shroud—Turbine Wheel	17.	Ring—Piston	23.	Ring—Snap
2.	Housing—Compressor	11.	Ring—Turbine Piston	18.	Collar—Thrust	24.	Bearing
6.	Housing—Turbine	12.	Screw	19.	Washer—Inboard Thrust	25.	Washer—Bearing
7.	Nut—Self-Locking	13.	Lockplate	20.	Bearing	26.	Ring—Snap
8.	Wheel—Compressor	14.	Backplate Assy.	21.	Washer—Bearing	27.	Housing—Center
9.	Shaft—Turbine Wheel Assy.	15.	Ring—Seal	22.	Ring—Snap	28.	Coupling—"V" Band
		16.	Spacer—Thrust				

Fig. 16 – TV61 Turbocharger Details and Relative Location of Parts.

3. Position the turbine wheel of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut from the shaft. If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

   NOTICE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Press the compressor wheel from the wheel shaft assembly.

5. Withdraw the wheel shaft assembly from the center housing. The wheel shroud, which is not retained, will fall free when the wheel shaft is removed.

6. Remove and discard the turbine piston ring from the wheel shaft.

7. Bend down the lock tabs and remove the four bolts and lockplates securing the backplate assembly to the center housing and remove the backplate assembly. Tap the backplate lightly to remove it from the center housing recess.

8. Remove and discard the seal ring from the groove in the center housing.

9. Remove the thrust spacer and piston ring(s) from the backplate assembly. Discard the piston ring(s).

10. Remove the thrust collar, inboard thrust washer, bearing, bearing washer and snap ring from the center housing. Discard the thrust washer, bearing, washer and snap ring.

11. Remove the snap ring, bearing, bearing washers and snap ring from the opposite end of the center housing. Discard the snap rings, bearing and washers.

Cleaning

Before cleaning, inspect all of the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non–caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts throughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or cramped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the backplate for wear or damaged bore (piston ring groove).

Inspect the housing for contact with the rotating parts.

The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished. Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts. It is recommended that the seal ring, piston rings, bearings, snap rings, lockplates and bolts be replaced at time of disassembly.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

TO4B Turbocharger – Fig. 15.

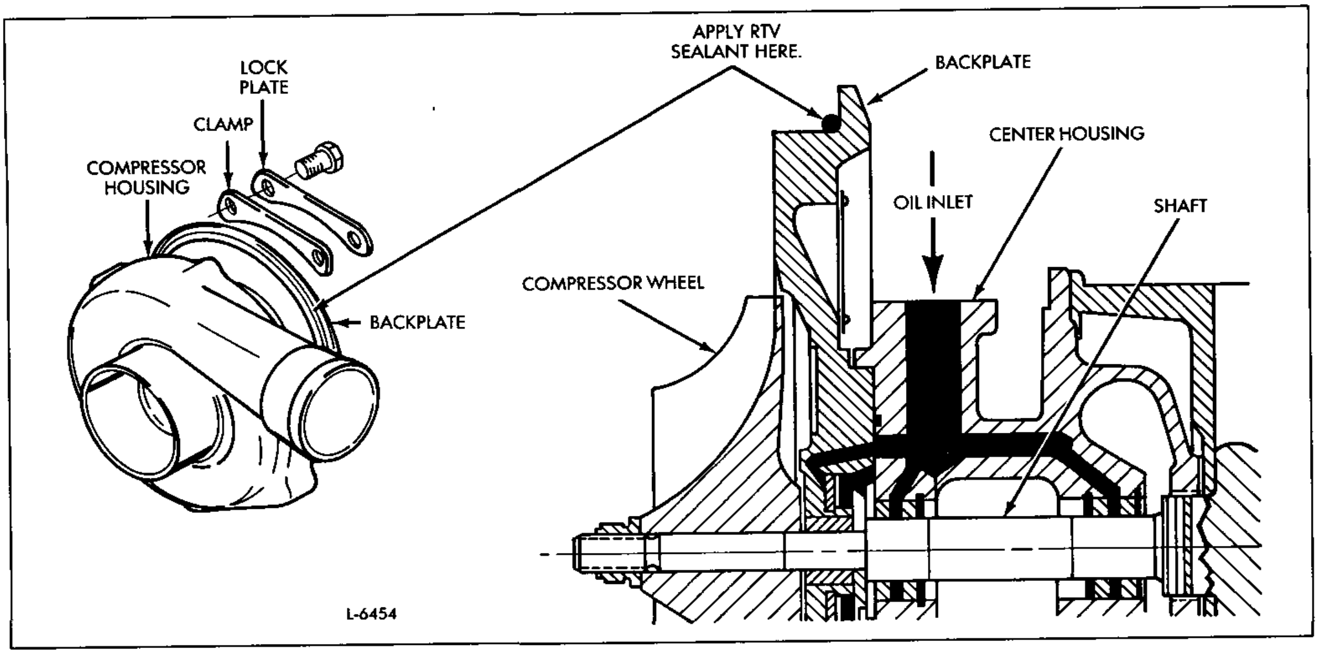
1. Lubricate the new bearings with clean engine oil.
2. Install a new snap ring, bearing and snap ring in the turbine end of the center housing, using snap ring pliers J 28507.
3. Install a new snap ring, bearing and snap ring in the compressor end of the center housing, using snap ring pliers J 28507.
4. Fill the piston ring groove in the turbine wheel shaft assembly with high vacuum silicone grease. Then install the piston ring on the wheel assembly.
5. Position the wheel shroud on the wheel of the shaft assembly and insert the shaft assembly into the center housing as far as it will go.

   NOTICE: Be careful not to scuff or scratch the bearings when installing the shaft and do not force the piston ring into the center housing bore.

6. Place the turbine wheel shaft assembly, shroud and center housing upright in a suitable holding fixture as shown in Fig. 8. If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.
7. Lubricate the thrust collar and thrust bearing with clean engine oil and install the thrust collar on the shaft of the turbine wheel assembly. Then install the thrust bearing in the groove of the collar and slide the assembled parts down against the center housing so that the pins engage the holes in the thrust bearing.
8. Install a new piston ring on the thrust collar.

   NOTICE: To avoid breakage, do not force the piston ring into place.

9. Install a new seal ring in the groove at the compressor end of the center housing.



● Fig. 17 – Application of RTV Sealant

10. Install the backplate assembly over the shaft and carefully guide the piston ring on the shaft into the backplate bore, ring gap first.

   - On engine applications where crankcase vapors are routed to the breather system and into the air intake of the T04B turbocharger, oil seepage may be experienced between the turbocharger compressor housing and the backplate area. If seepage is observed in this area, apply a small uniform bead of high temperature RTV sealant on the outside diameter of the backplate (Fig. 17)

   - **NOTICE:** Make certain that the sealant does not cause compressor housing misalignment, which can result in compressor wheel–to–housing contact and resultant damage.

   - Surfaces must be clean and dry. Application instructions for the sealant are normally available on the RTV tube or package.

11. Align the oil feed holes in the center housing and the backplate assembly and attach the backplate to the center housing with bolts and new lockplates. Tighten the bolts to 75–90 **lb–in** (8–10 N·m) torque and bend the lockplate tabs up against the side of the bolt heads.

   NOTICE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

12. With the compressor wheel at room temperature, position it over the shaft.

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the locknut on the shaft. Tighten the nut to 18–20 **lb–in** (2 N·m) torque above the drag torque required to bottom the locknut.

   NOTICE: Bottoming of the locknut will be indicated by the sharp increase above the drag torque observed while running the nut down.

14. Retighten the locknut through an angle of 90°. This additional tightening will result in stretching the shaft .0055″ to .0065″ in length. *Tighten the retaining nut in such a manner as not to impose a bending load on the shaft.*

15. Check the bearing axial end play:

   a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 9.

   b. Fasten the dial indicator and magnetic base (J 7872–2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 9).

   c. Move the shaft axially back and forth by hand. The total indicator reading should be between .004″ and .009″. If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing as marked at disassembly against the center housing and secure it in place with clamps, new lockplates and bolts. Tighten the bolts to 100–130 **lb–in** (11–15 N·m) torque and bend the tabs of the lockplates up against the bolts.

17. Position the compressor housing as marked at disassembly against the center housing and secure it in place with clamps, new lockplates and bolts. Tighten the bolts to 100–130 **lb–in** (11–15 N·m) torque and bend the tabs of the lockplates up against the bolts.

18. Check the shaft radial movement:

    a. Position the magnetic base J 7872–2 with the swivel adaptor J 7872–3 on the flat surface of the turbine housing inlet flange as shown in Fig. 10.

    b. Fasten the dial indicator extension rod J 7872–1 to the dial indicator J 8001–3 and attach the dial indicator to the swivel adaptor.

    c. Insert the extension rod J 7872–1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

    NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

    d. Grasp each end of the rotating assembly (Fig. 10) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003″ and .007″. If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

19. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

20. Stamp the letter "R" in the lower left–hand corner of the name plate to identify that the turbocharger has been reworked.

TV61 Turbocharger – Fig. 16.

1. Lubricate the new bearings with clean engine oil.

2. Install a new snap ring, bearing washer, bearing and snap ring in the turbine end of the center housing.

3. Install a new snap ring, bearing washer and bearing in the compressor end of the center housing.

4. Install new piston rings on the thrust spacer and gently insert the spacer into the backplate assembly. *Do not force the piston into place.*

5. Make sure the compressor bearing is in place, then position the inboard thrust washer flat against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing.

6. Install the thrust collar snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.

7. Install a new seal ring in the groove at the compressor end of the center housing.

8. Align the oil feed holes in the center housing and the backplate assembly and attach the backplate to the center housing with four bolts and new lockplates. Tighten the bolts to 80–100 **lb–in** (9–11 N·m) torque and bend the lockplate tangs up against the side of the bolt heads.

NOTICE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

9. Install a new piston ring on the turbine wheel shaft assembly. Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.

10. Position the wheel shroud against the center housing and insert the wheel shaft assembly through the wheel shroud and into the center housing. *Be careful not to scuff or scratch the bearings when installing the shaft.*

11. Place the turbine wheel shaft assembly, shroud, center housing and backplate upright in a suitable holding fixture (Fig. 8). If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

12. With the compressor wheel at room temperature, position it over the shaft.

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the retaining nut. Tighten the nut to 125–150 **lb–in** (14–17 N·m) torque to seat the compressor wheel against the thrust spacer.

14. Loosen the nut and inspect the nut face and front face of the compressor wheel to be sure they are smooth and clean.

15. *Retighten the nut to 35–55* **lb–in** *(4–6 N·m) torque.*

16. Continue to tighten the retaining nut until the shaft increases in length .009″–.010″. Tighten the nut in

such a manner as not to impose bending loads on the shafts.

If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35–55 **lb–in** (4–6 N·m) torque. Then continue to tighten the nut through an angle of 120–130° turn (90° is 1/4 turn).

17. Check the bearing axial end play:

    a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 9.

    b. Fasten the dial indicator and magnetic base (J 7872–2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 9).

    c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be between .003" and .010". If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

18. Position the turbine housing as marked at disassembly against the center housing and secure it in place with the "V" band coupling. Position the "V" band coupling between the turbine housing and center housing so that the bolt end does not interfere with the turbine housing. Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak and/or turbine wheel damage. Tighten the toggle nut as follows:

    a. Lubricate the toggle bolt threads with a high temperature anti–seize compound, such as Jet Lube (Mil Spec A–907D), or equivalent.

    b. Tighten the nut on the "V" band toggle bolt to approximately 160 **lb–in** (18 N·m) torque.

    NOTICE: To avoid turbocharger damage, do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

    c. Loosen the "V" band coupling nut to approximately 50 **lb–in** (6 N·m) torque, then retorque the nut to 152–168 **lb–in** (17–19 N·m) torque.

19. Position the compressor housing as marked at disassembly against the backplate and secure it in place with the "V" band coupling. Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110–130 **lb–in** (12–15 N·m) torque.

20. Check the shaft radial movement.

    a. Position the magnetic base J 7872–2 with the swivel adaptor J 7872–3 on the flat surface of the turbine housing inlet flange as shown in Fig. 10.

    b. Fasten the dial indicator extension rod J 7872–1 to the dial indicator J 8001–3 and attach the dial indicator to the swivel adaptor.

    c. Insert the extension rod J 7872–1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

    NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

    d. Grasp each end of the rotating assembly (Fig. 10) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between ,003" and .007". If the displacement does not fall within these limits disassemble and repair or replace the rotating assembly.

21. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

22. Stamp the letter "R" in the lower left–hand corner of the name plate to identify that the turbocharger has been reworked.

Install Turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

3. Place the turbocharger assembly into position. Use a new gasket between the exhaust manifold adaptor or exhaust outlet flange and the turbine housing flange.

   When attaching the exhaust flange or adaptor to the turbine housing, be sure the inner diameter of the adaptor or flange is the same as the turbine inner diameter. The turbine opening in a T04B turbocharger is 2.581" and the TV61 turbocharger is 3.100".

4. Secure the T04B turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the bracket.

   When self–locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is

full thread engagement (at least one full thread above the nut) of the self–locking nuts on the bolts.

5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

6. Tighten the turbocharger to exhaust manifold adaptor (T04B) or exhaust outlet flange (TV61) bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. After installing a rebuilt or new turbocharger, it is very *important that all of the moving parts of the* turbocharger center housing be lubricated as follows:

   a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 14).

   b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

   c. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

   d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig – 69 kPa at idle speed).

   CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

   The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds.

   NOTICE: Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

10. Check all connections, ducts and gaskets for leaks.

11. Operate the engine at rated output and listen for sound of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

   NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TV7301 AND TV8101 TURBOCHARGERS

•Turbocharger Safety

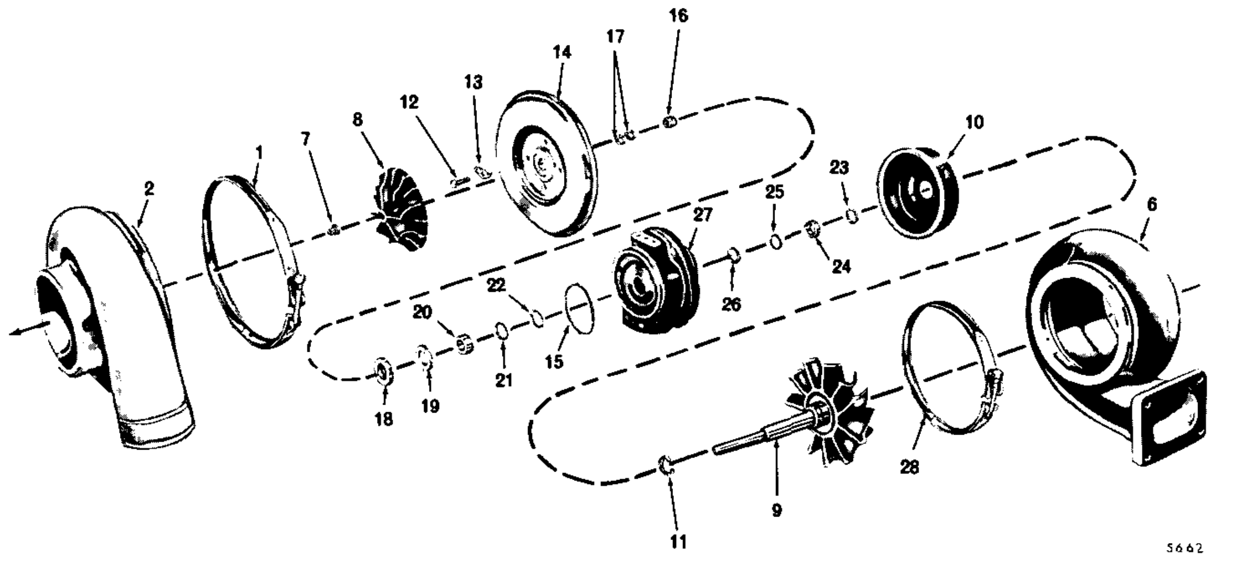
Effective February of 1988, a new guard assembly was installed over the compressor inlets of Airesearch TV 7301 and TV 8101 turbochargers. The new two–piece assembly is intended to protect the service technician from the exposed turbocharger compressor wheel when the engine is operated with the air inlet piping removed from the compressor housing. The guard assembly also prevents foreign objects from being ingested by the turbocharger and causing damage.

The guard assembly is permanently retained by a bead machined on the end of the compresor housing. This bead became a standard feature on Airesearch turbochargers in the fourth quarter of 1978.

Compressor housings for TV 7301 and TV 8101 *turbochargers are serviced with the inlet guard installed.*

CAUTION: The guard assembly forms a permanent part of the compressor housing and must not be removed. Removing the guard will result in a potential for personal injury from the exposed, rotating compressor wheel. Attempting to remove the guard will also result in damage to the guard and the housing. A damaged guard or housing cannot be reused.

Because of the added margin of safety provided by the inlet guard assembly, DDC recommends having the guard installed on early TV 7301 and TV 8101 turbochargers when the air inlet piping is removed for any reason.



1. Coupling—"V" Band	10. Shroud—Turbine Wheel	17. Ring—Piston	23. Ring—Snap
2. Housing—Compressor	11. Ring—Turbine Piston	18. Collar—Thrust	24. Bearing
6. Housing—Turbine	12. Screw	19. Washer—Inboard Thrust	25. Washer—Bearing
7. Nut—Self-Locking	13. Lockplate		26. Ring—Snap
8. Wheel—Compressor	14. Backplate Assembly	20. Bearing	27. Housing—Center
9. Shaft—Turbine Wheel Assembly	15. Ring—Seal	21. Washer—Bearing	28. Coupling—"V"
	16. Spacer—Thrust	22. Ring—Snap	

Fig. 18 – TV7301 and TV8101 Turbocharger Details and Relative Location of Parts

CAUTION: The guard assembly cannot be installed on certain turbochargers becuase they have smaller (5.58") compressor inlet diameters. To avoid the potential for personal injury, shield J 26554-A (Fig. 4) should be installed whenever the air inlet piping is removed from these turbochargers.

Remove Turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.
2. Disconnect the air inlet hose attached to the compressor housing.
3. Remove the oil inlet line from the top of the center housing.
4. Remove the oil outlet line from the bottom of the center housing.
5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket. Then lift the turbocharger assembly away from the engine and place it on a bench.
7. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material.

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembly and proceed as follows:

Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

1. Refer to (Fig. 18) and loosen the "V" band coupling (1) securing the compressor housing (2) to the backplate assembly (14) and remove the compressor housing and "V" band.

NOTICE: Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen the "V" band coupling (28) securing the turbine housing (6) to the center housing (27). Remove the turbine housing from the center housing. Tap the housing with a soft hammer if force is needed for removal.

3. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 19). Remove the wheel nut (7) from the shaft. If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

NOTICE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Press the compressor wheel (8) from the wheel shaft assembly (9).

5. Withdraw the wheel shaft assembly (9) from the center housing. The wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.

6. With the TV7301 and TV8101 turbocharger remove and discard the turbine piston ring (11) from the wheel shaft.

7. Bend down the lock tabs and remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (27) and remove the backplate assembly. Tap the backplate lightly to remove it from the center housing recess.

8. Remove and discard the seal ring (15) from the groove in the center housing.

9. Remove the thrust spacer (16) and piston ring(s) (17) from the backplate assembly. Discard the piston ring(s).

10. Remove the thrust collar (18), inboard thrust washer (19), bearing (20), bearing washer (21) and snap ring (22) from the center housing. Discard the thrust washer, bearing, washer and snap ring.

11. Remove the snap ring (23), bearing (24), bearing washers (25) and snap ring (26) from the opposite end of the center housing. Discard the snap rings, bearing and washers.

Cleaning

Before cleaning, inspect the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non–caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel for signs of rubbing or wear. For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

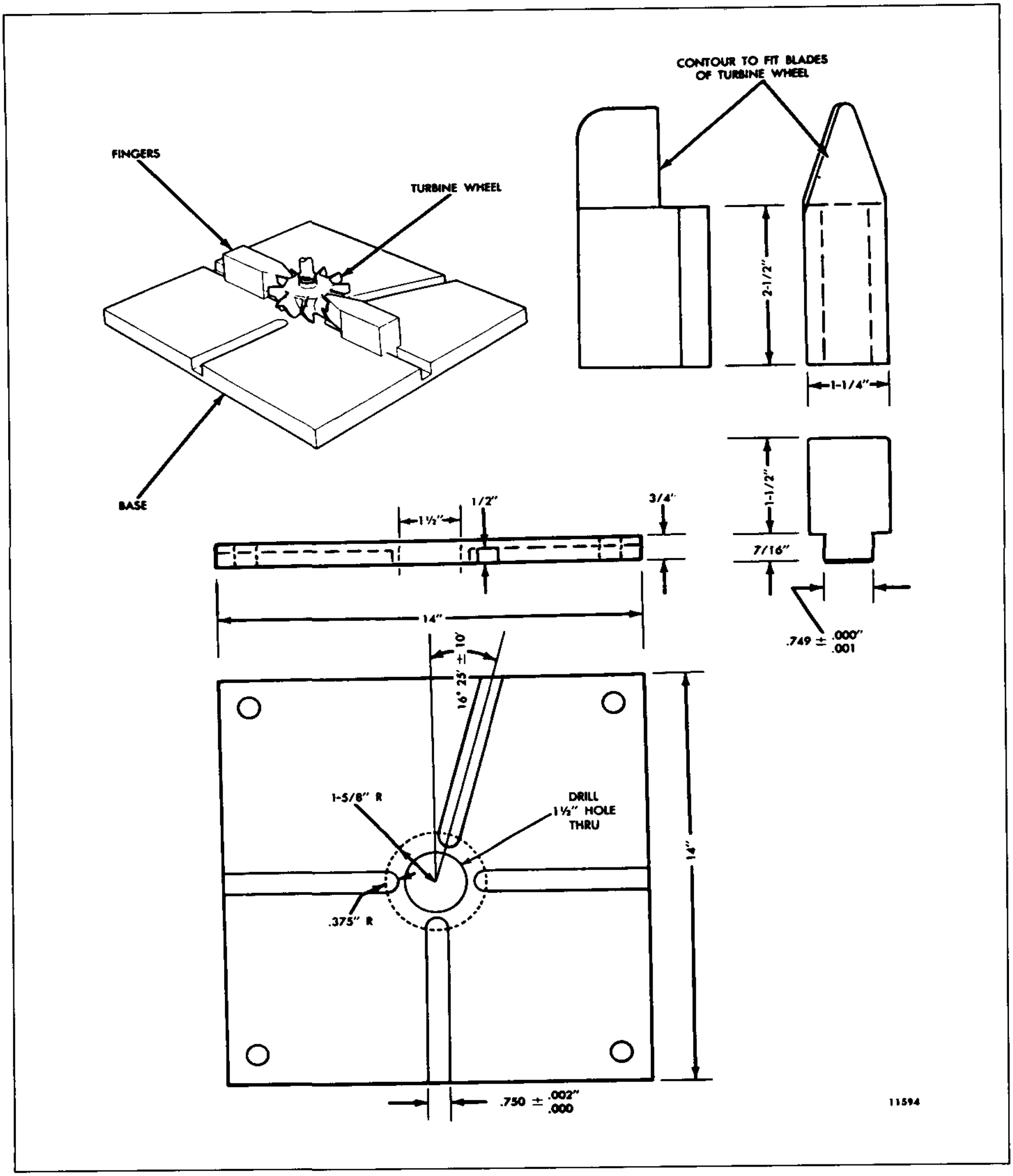


Fig. 19 – Turbocharger Holding Fixture

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the backplate for wear or damaged bore (piston ring groove).

Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished. Use a silicone carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

It is recommended that the piston rings, thrust washers, bearing, bearing washers and snap rings be replaced at time of disassembly.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to (Fig. 18) for parts orientation and proceed as follows:

1. Lubricate the bearings (20 and 24) with clean engine oil.
2. *Install* a new snap ring (26), bearing washer (25), bearing (24) and new snap ring (23) in the turbine end of the center housing (27).
3. Install a new snap ring (22), bearing washer (21) and bearing in the compressor end of the center housing. Install the current inboard thrust bearing (three oil grooves) with the smooth side against the center housing.
4. Install a new piston ring(s) (17) on the thrust spacer (16) and gently insert the spacer into the backplate assembly (14). *Do not force the piston ring(s) into place.*
5. Make sure the compressor bearing is in place, then position the new inboard thrust washer (19) flat against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing.
6. Install the thrust collar (18) snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.
7. Install a new seal ring (15) in the groove at the compressor end of the center housing.
8. Align the oil feed holes in the center housing (27) and the backplate assembly (14) and attach the backplate to the center housing with four bolts (12) and new lockplates (13). Tighten bolts to 80–100 ***lb–in*** (9–11 N·m) torque and bend the lockplate tangs up against the side of the bolt heads.

   NOTICE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

9. Install a new turbine piston ring (11) on the wheel shaft assembly. Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.
10. Position the wheel shroud (10) against the center housing (27) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing. Be careful not to scuff or scratch the bearings when installing the shaft.
11. Place the turbine wheel shaft assembly, shroud, center housing and backplate upright in a suitable holding fixture (Fig. 41). If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.
12. With the compressor wheel at room temperature, position it over the shaft.

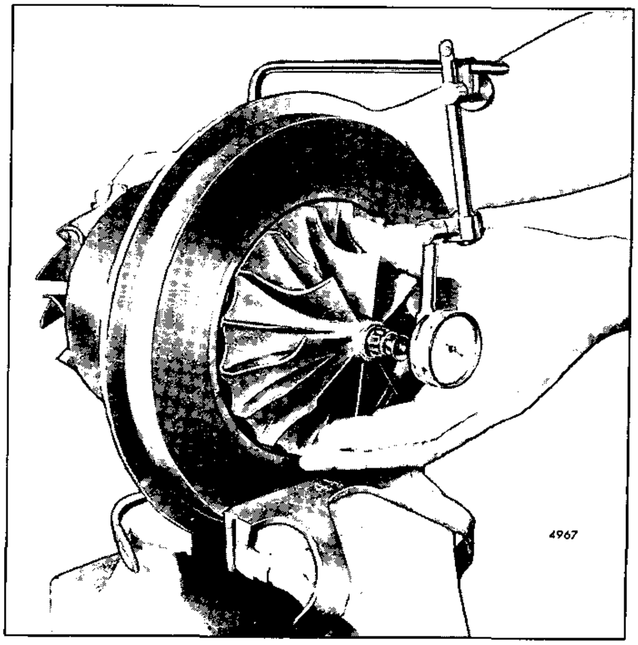


Fig. 20 – Checking Bearing Axial End Play

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the retaining nut. Tighten the nut to 125–150 ***lb–in*** (14–17 N·m) torque to seat the compressor wheel against the thrust spacer.

14. Loosen the nut and inspect the nut face and front face of the compressor wheel to be sure they are smooth and clean.

15. Retighten the nut to 35–55 ***lb–in*** (4–6 N·m) torque.

16. Continue to tighten the retaining nut until the shaft increases in length .009"–.010". Tighten the nut in such a manner as not to impose bending loads on the shafts.

    If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35–55 ***lb–in*** (4–6 N·m) torque. Then continue to tighten the nut through an angle of 120–130° turn for the TV71 and TV81 (90° = 1/4 turn).

17. Check the bearing axial end play:

    a. Clamp the center housing assembly in a bench vise equipped with soft jaws (Fig. 20).

    b. Fasten the dial indicator and magnetic base (J 7872–2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 20).

    c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be between .003" and .010". If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

18. Position the turbine housing (6) as marked at disassembly against the center housing (27) and secure it in place.

    Position the "V" band coupling (28) between the turbine housing and center housing so that the "T" bolt end does not interfere with the turbine housing.

    NOTICE: Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak and/or turbine wheel damage.

    Then tighten the "V" band coupling nut as follows:

    a. Lubricate the toggle bolt threads with a high temperature anti–seize compound, such as Jet Lube (Mil Spec A–907D), or equivalent.

    b. Tighten the nut on the "V" band bolt to approximately 160 ***lb–in*** (18 N·m) torque.

    NOTICE: To avoid component damage, do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

    c. Loosen the "V" band coupling nut to approximately 50 ***lb–in*** (6 N·m) torque, then retorque the nut to 152–168 ***lb–in*** (17–19 N·m) torque.

19. Position the compressor housing (2) as marked at disassembly against the backplate (14) and secure it in place with the "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110–130 ***lb–in*** (12–15 N·m) torque.

20. Check the shaft radial movement:

    a. Position the magnetic base J 7872–2 with the swivel adaptor J 7872–3 on the flat surface of the turbine housing inlet flange (Fig. 21).

    b. Fasten the dial indicator extension rod J 7872–1 to the dial indicator J 8001–3 and attach the dial indicator to the swivel adaptor.

    c. Insert the extension rod J 7872–1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

    NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

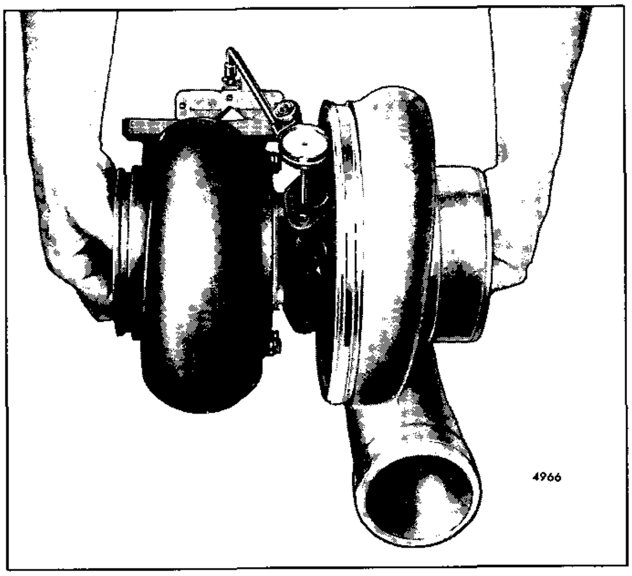


Fig. 21 – Checking Shaft Radial Movement

d. Grasp each end of the rotating assembly (Fig. 21) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003" and .007". If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

21. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

22. Stamp the letter "R" in the lower left–hand corner of the name plate to indicate that the turbocharger has been reworked.

Install Turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

   Be sure gaskets are installed at the three mounting bracket to flywheel housing attaching bolts.

3. Place the turbocharger assembly into position on the mounting bracket. Use a new gasket between the exhaust manifold adaptor and the turbine housing flange.

   When attaching the exhaust flange or adaptor to the turbine housing, be sure the inner diameter of the flange or adaptor is the same as the turbine housing inner diameter.

4. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the bracket.

   When self–locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self–locking nuts on the bolts.

5. Slide the blower air inlet hose over the compressor housing outlet opening. Then center the hose between the turbocharger and the blower air inlet housing and secure the clamps with the "T" section positioned away from the parting line on the air inlet housing.

6. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. After installing a rebuilt or new turbocharger, it is very important that all moving parts of the turbocharger center housing be lubricated as follows:

   a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing.

   b. Fill the bearing housing cavity with clean engine oil.

   c. Reinstall the oil line. Clean off any spilled oil.

   d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psi or 69 kPa at idle speed).

   CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

   The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

10. Check all ducts and gaskets for leaks.

11. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

    NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER (SCHWITZER)

The Schwitzer turbocharger, Model 3LM (2.7 square inches), (Figs. 1 and 3) is comprised of a centrifugal compressor which shares a bearing system and rotor shaft with an exhaust gas–driven turbine. The turbocharger boosts the blower intake pressure of an engine above that which would prevail if the engine were naturally aspirated. The rotating assembly is supported radially by a free–floating, pressure lubricated, sleeve type bearing. Axial end play is controlled by a stationary pressure lubricated thrust bearing, with attendant hardware in the compressor end of the bearing housing.

The oil cavity is separated from the air and exhaust chambers by piston type seal rings located in the cylindrical bores at both axial extremities of the bearing housing.

The external configuration of both the Schwitzer and the Airesearch turbochargers are identical and hardware connections will not change. However, the internal components are different.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearing, thrust bearing and thrust sleeve. The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

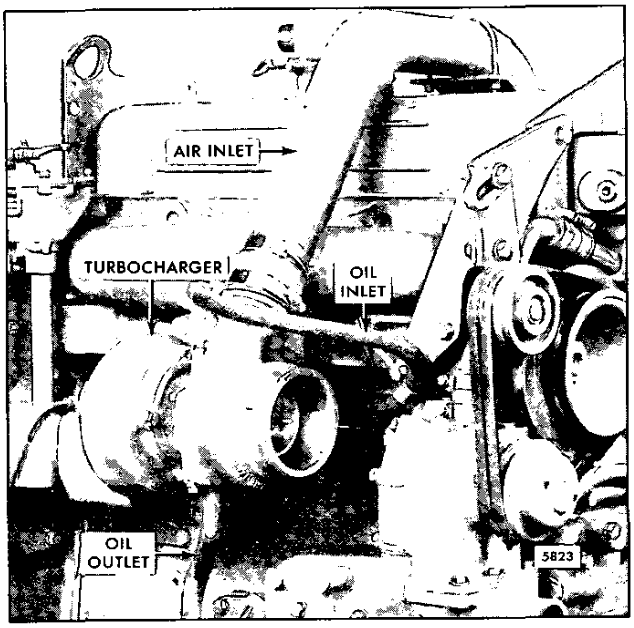


Fig. 1 – Model 3LM Turbocharger Assembly

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre–lubricated as outlined under *Install Turbocharger.*

NOTICE: Failure to perform the pre–lubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Periodic Inspection

NOTICE: A turbocharger compressor inlet shield, J 26554–A (Fig. 2), is available for use anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects entering the turbocharger and prevents a service technician from touching the moving impeller. The use of this shield *does not* preclude any other saftey practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

NOTICE: Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Troubleshooting Turbocharger* in Section 3.0. Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTICE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated.

For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1, Fig. 3. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine. *Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housing.*

Check for signs of oil leaking from the turbocharger housing. Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2, Fig. 3.

Oil pull–over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pull–over.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3, Fig. 3.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal:

1. A worn or defective oil seal, which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil it indicates leakage.

If this test does not show leakage patterns the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

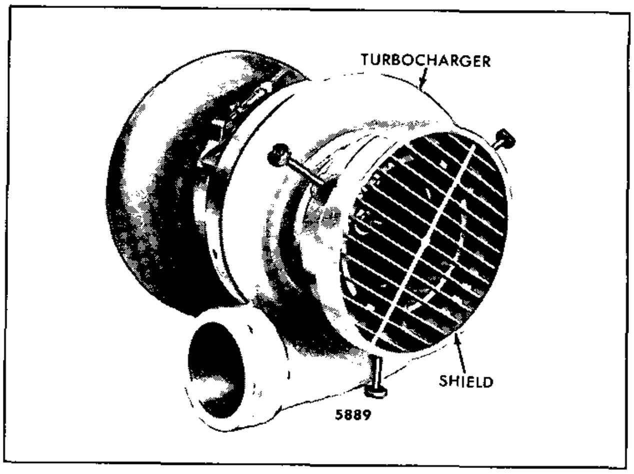


Fig. 2 – Inlet Shield (J 26554–A)

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that turbocharger oil drain line is ununrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove the air intake ducting. Inspect inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, the impeller cavity behind the impeller, and the backplate annulus with a suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of "Spot–Check" developer type SKD–MF, or *equivalent.*

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm–up the engine to normal operating temperature.

10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

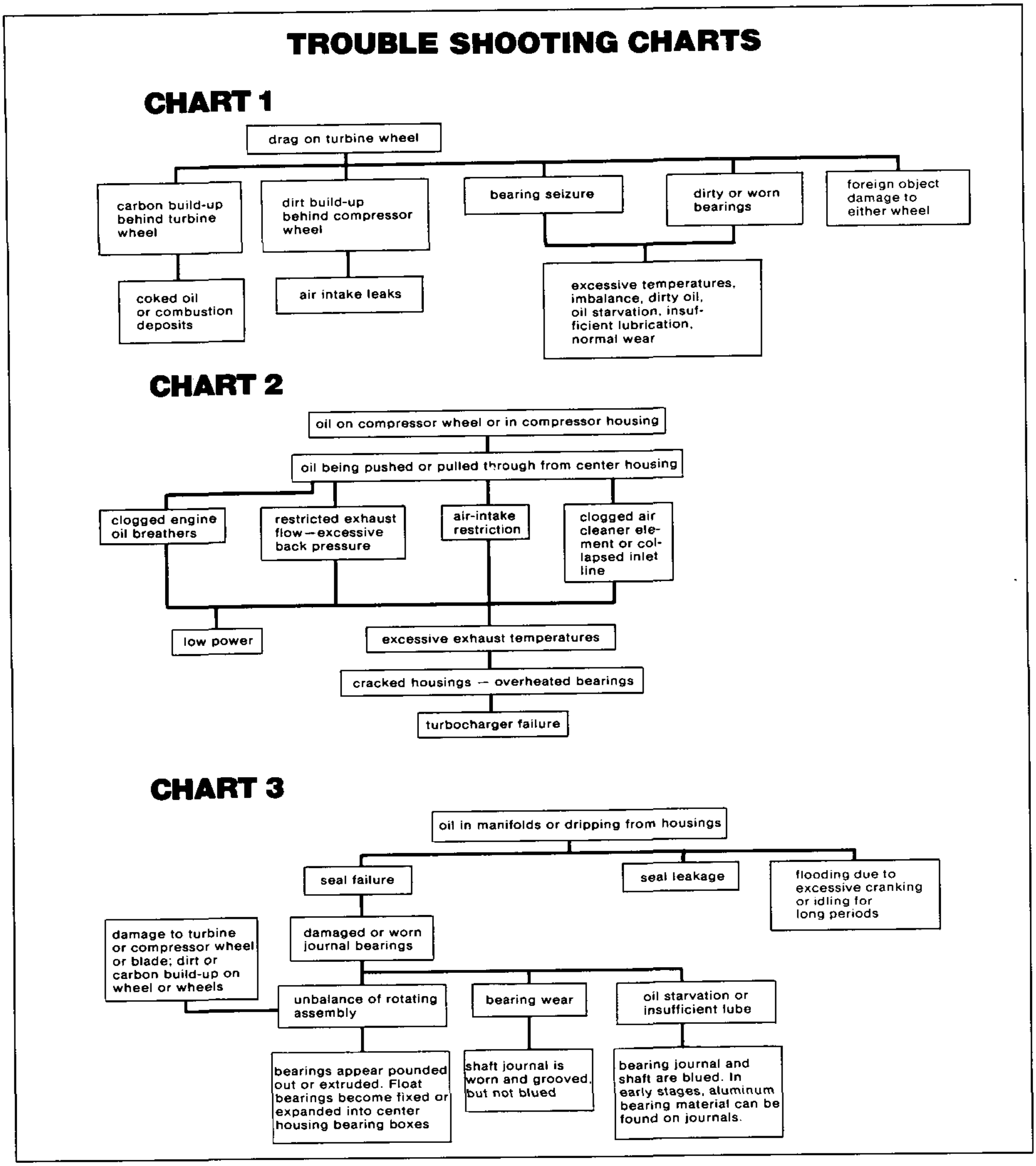


Fig. 3 – Inspection Checks for Turbocharger

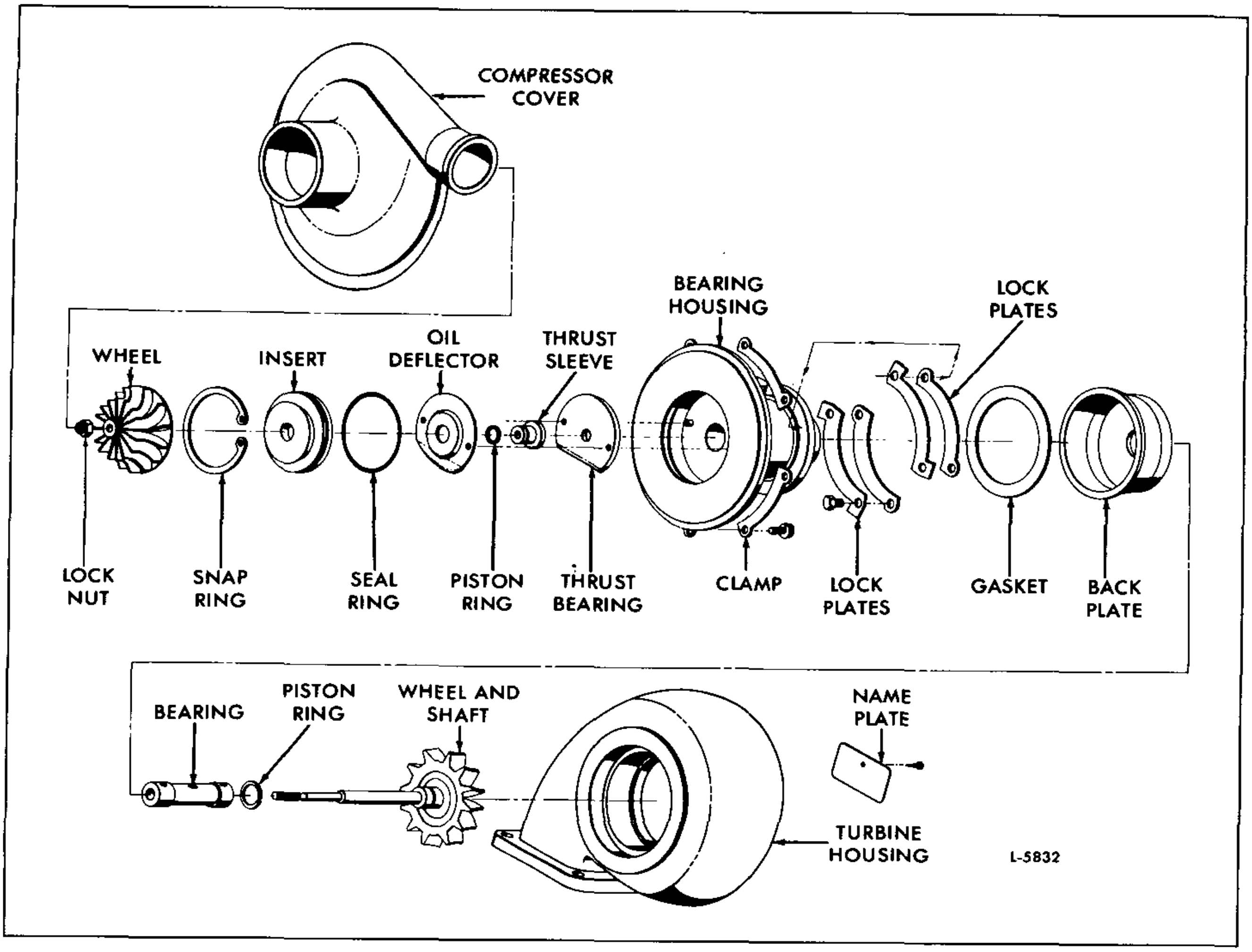


Fig. 4 – Model 3LM Turbocharger and Relative Location of Parts

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then *remove the compressor housing. Evidence of* compressor end shaft seal oil leakage will be observed as oil streaks in the "Spot–Check" developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. *If leakage is detected, and oil is positively not entering* through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Disconnect the air inlet connection and the exhaust outlet connection from the compressor housing and turbine housing respectively. This will permit inspection of the compressor and turbine wheels. Spin and wobble the rotor assembly variously by hand for *evidence of wheel to turbine housing and impeller to* compressor housing contact.

2. Remove the oil inlet and outlet lines from the top and bottom of the bearing housing.

3. Attach a suitable lifting sling to the turbocharger.

4. Remove the nuts and lock washers securing the turbocharger to the mounting bracket. Lift the turbocharger from the engine.

5. Cover the oil inlet and outlet openings and the air inlet and exhaust openings on the engine to prevent the entry of foreign material.

Disassemble Turbocharger

CAUTION: To avoid personal injury during disassembly it is recommended that safety glasses be used.

1. Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembly and proceed as follows:

   NOTICE: Exercise care when removing the compressor housing and turbine housing from the bearing housing to prevent damage to the compressor and turbine wheels.

2. Secure the turbine housing mounting flange in a vise and bend back the lock tabs on the lock plates. Then remove the four screws, two lock plates and two clamps.

3. Remove the rotating assembly and compressor cover as an assembly out of the turbine housing and invert it and place it on a work bench with the turbine wheel facing up.

4. Remove the eight screw and lock washer assemblies and four clamps. Then remove the rotating assembly from the compressor cover.

5. With the turbine wheel lug of the rotating assembly in a 1″ wrench (Fig. 5), remove and discard the compressor wheel lock nut.

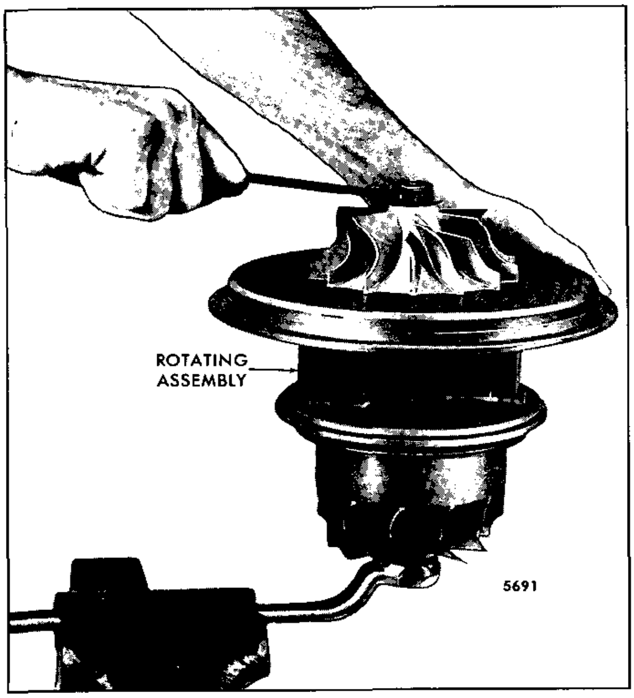


Fig. 5 – Removing Compressor Wheel Lock Nut

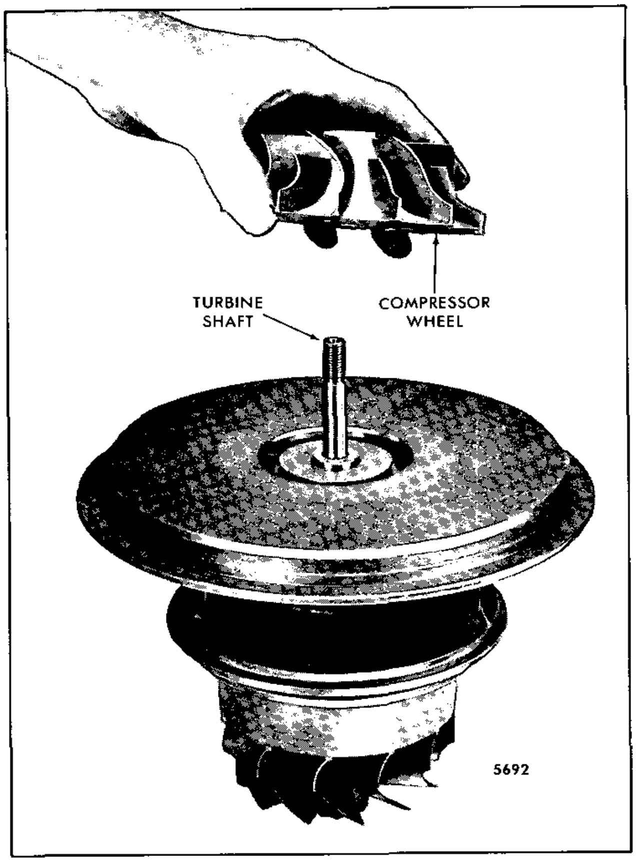


Fig. 6 – Removing Compressor Wheel from Turbine Shaft

6. Remove the compressor wheel from the turbine shaft assembly by hand (Fig. 6). The wheel is a slip fit on the shaft.

7. Remove the external snap ring from the compressor end of the bearing housing (Fig. 7). Use medium size internal snap ring pliers and restrain the ring with a shop cloth to prevent injury, in the event the ring goes astray.

8. Remove the compressor insert from the bearing housing by prying evenly and gently with screw drivers placed under the lip of the insert (Fig. 8).

   NOTICE: To avoid turbocharger damage if the insert tilts and binds, tap it back into place and repeat the procedure. *Do not force* the insert from the bearing housing.

9. Remove the oil deflector, outer piston ring, thrust sleeve, thrust bearing (discard) and inner piston ring from the cavity in the bearing housing. *Do not remove the dowels from the bearing housing.*

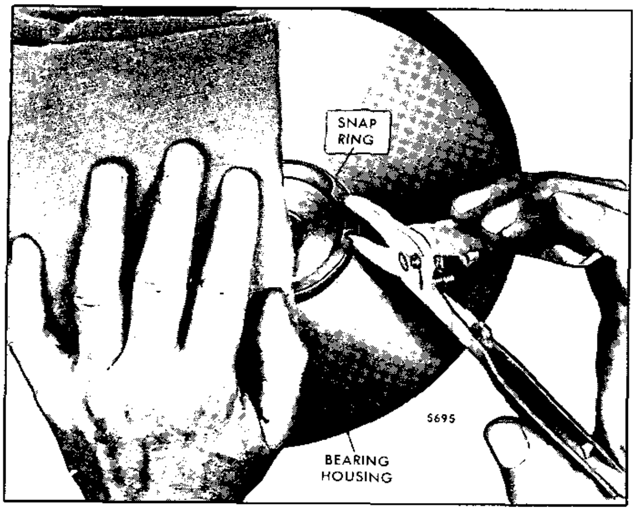


Fig. 7 – Removing External Snap Ring from Bearing Housing

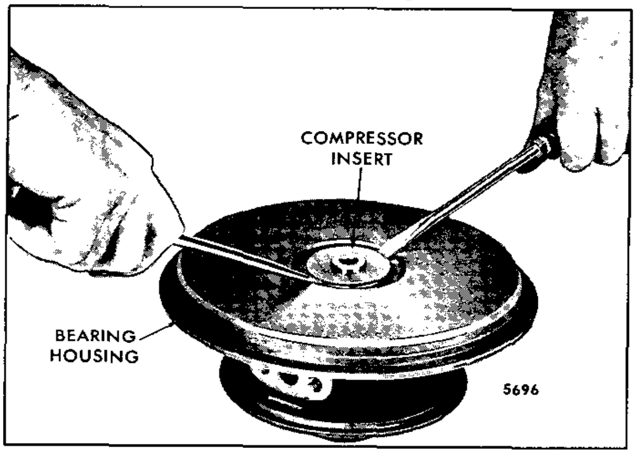


Fig. 8 – Removing Compressor Insert from Bearing Housing

10. Tap the turbine shaft assembly gently with a plastic faced mallet to release it from the bearing housing (Fig. 9).

11. Remove the turbine wheel and shaft assembly. The shaft should slip freely out of the bearing after the initial release by tapping.

12. Remove and discard the turbine shaft bearing from the bearing housing bore (Fig. 10).

13. Separate the backplate and gasket from the bearing housing. Discard the gasket.

NOTICE: If the seal ring bore in the bearing housing is encrusted with carbon, preventing removal of the bearing components, scrape away the carbon with a sharp–edged tool. Be careful not to scratch or gouge the seal ring bore surface.

14. Remove and discard the seal ring from the turbine wheel–and–shaft by prying and breaking with a screw driver. Take care not to mar the hub or groove surfaces of the turbine wheel.

Cleaning Procedures

1. Bearing Housing and Dowel Assembly:
   a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.
   b. Immerse briefly in safety solvent to remove any traces of oily residue.
   c. Dry with clean compressed air, again taking care that all drilled oil passages are thoroughly cleaned.

   - **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

   d. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.
2. Compressor Wheel:
   a. Immerse briefly in safety solvent to remove any traces of oily residue.
   b. Dry with clean compressed air.
   c. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.
3. Turbine Wheel–and–Shaft Assembly:
   a. Immerse briefly in safety solvent to remove any traces of oily residue.
   b. Dry with clean compressed air.
   c. Mask the entire shaft section with either appropriately sized rubber hose or adhesive backed cloth tape.
   d. Vapor blast or dry hone the entire turbine wheel and the hub to total cleanliness, taking care not to concentrate on the seal ring groove.
   e. Remove the masking material.
   f. Mount the small diameter shaft section in a lathe chuck, taking care not to mar the shaft surface. *Lightly* polish the bearing journal section of the shaft, at 300 to 600 rpm, with 400 grit abrasive paper and clean engine oil.
   g. Reimmerse briefly in clean safety solvent, agitating moderately by hand to help loosen any remaining particles of foreign material.

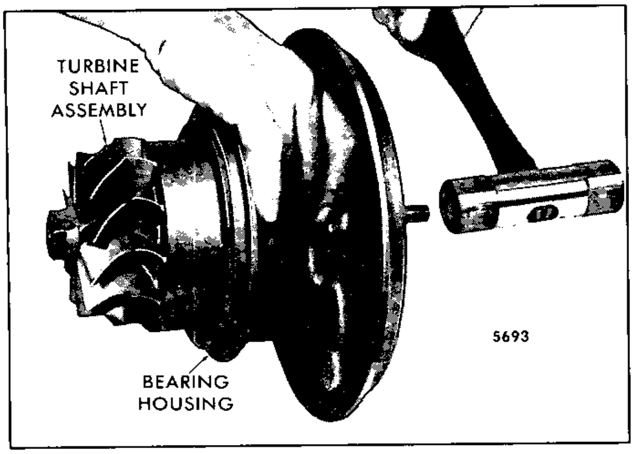


Fig. 9 – Tapping Turbine Shaft Assembly from Bearing Housing

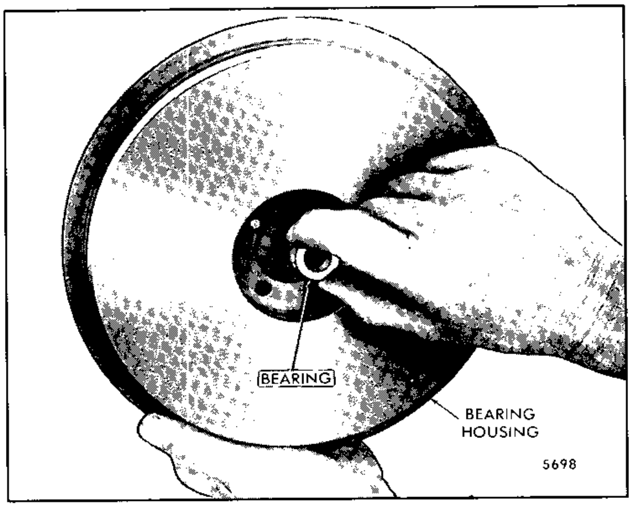


Fig. 10 – Removing Turbine Shaft Bearing from Bearing Housing

h. Dry with clean compressed air.

i. Oil the shaft surfaces liberally to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

4. Compressor Housing:

 a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.

 b. Immerse briefly in safety solution to remove any traces of oily residue.

 c. Dry with clean compressed air.

 d. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

5. Turbine Housing and Turbine Backplate:

 a. Immerse briefly in safety solvent to remove any traces of oily residue.

 b. Dry with clean compressed air.

 c. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

6. Clamp Bands:

 a. Immerse in safety solvent until foreign material deposits have been softened or dissolved, agitating moderately and occasionally by hand.

 b. Dry with clean compressed air.

 c. Wrap *immediately* in a clean, dry plastic bag until inspection and reuse.

7. Small Internal Parts:

 a. Immerse briefly in clean safety solvent to remove any traces of oily residue.

 b. Wipe dry with a clean shop rag.

 c. Oil liberally to prevent rust and wrap *immediately* in a clean, dry plastic bag until inspection and reuse.

Inspection

1. Bearing Housing and Dowel Assembly:

 NOTICE: The installation of the two groove pins into the bearing housing of Schwitzer 3LM turbocharger used on 4–53 engines is an extremely critical operation requiring special tools not generally available to the service technician. Since improper assembly of the pins into the housing can result in high turbocharger oil flow, seal leakage and serious turbocharger damage, the service technician should not attempt to replace them when worn or damaged. Instead, the bearing housing assembly incorporating the factory–installed pins should be used. Only the bearing housing assembly with factory–installed pins will be serviced.

 a. Inspect visually for evidence of cracks and fractures, pitting (as from corrosion or hot gas erosion) of gasket and other machined surfaces, and warpage of the turbine end flange. Replace if any of the above conditions are excessive.

 b. Closely inspect the bearing bore visually for evidence of surface distress. The condition of the bearings that were removed during disassembly will serve as a good indicator of probable bore

condition. Replace if the bore condition is sub–standard. The maximum bore diameter is .7505".

c. Install the turbine seal ring in its bore, inspect visually for full circle contact, and measure the ring gap with a feeler gage (Fig. 11). The gap range is .002" to .007". Replace if the ring fit is faulty. *Do not attempt to restore the bore condition by reaming or honing.*

2. Compressor Wheel:

Inspect visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the backplate. Replace if this damage is present. Slightly nicked vanes are acceptable. *Do not attempt to straighten bent vanes.*

3. Turbine Wheel and Shaft Assembly:

a. Inspect the wheel visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the back face. Replace if damaged. *Do not attempt to straighten bent vanes.*

b. Inspect the hub visually for evidence of smearing (as from high speed contact with the bearing housing bore) and for deterioration of the seal ring groove. Replace if damage is excessive.

c. Inspect bearing journals visually for evidence of other than superficial deterioration (as from a bearing failure). Replace if journal condition is sub–standard. The minimum journal diameter is .5611".

d. Measure the concentricity between the large and small turbine shaft diameters with a dial test indicator and vee–block (Fig. 12). Limit of eccentricity is .0006" total indicator reading. Replace if the measurement is excessive. *Do not attempt to straighten a bent shaft.*

4. Compressor Housing:

Inspect visually for evidence of contour damage (as from high speed wheel contact). Replace if damaged.

5. Turbine Housing and Backplate:

Inspect visually for evidence of contour damage (as from high speed wheel contact) and for evidence of excessive heat damage, to internal and flanged surfaces, such as cracking, pitting or warpage. Replace if damaged.

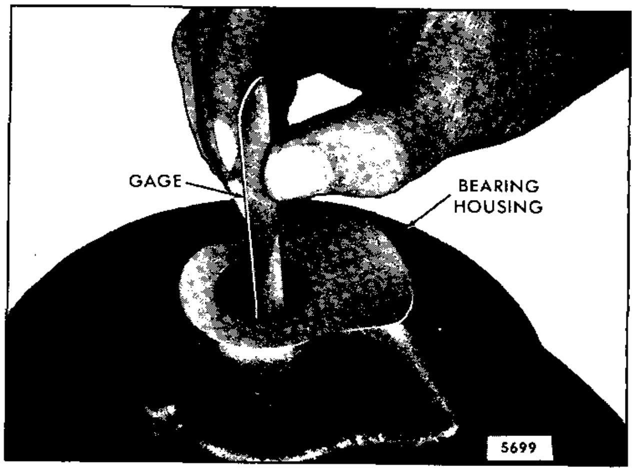


Fig. 11 – Checking Turbine Seal Ring Gap in Bearing Housing

6. Small Internal Parts:

a. Install the compressor seal ring in the insert bore, inspect visually for full circle contact and measure the ring gap with a feeler gage. Gap range is .002" to .007". Replace the insert if the ring fit is faulty. *Do not attempt to restore bore condition by reaming or grinding.*

b. Inspect both thrust rings visually for evidence of wear and scratching. Replace if damaged.

Assemble Turbocharger

1. Place the turbine housing in a vise with the four threaded holes facing up.

2. Lubricate a new piston ring with clean engine oil and install it in the ring grooves of the wheel and shaft assembly (Fig. 13). *Do not over expand the ring.*

3. Position the bearing housing, turbine end up (Fig. 14). Then install a new gasket and the turbine backplate.

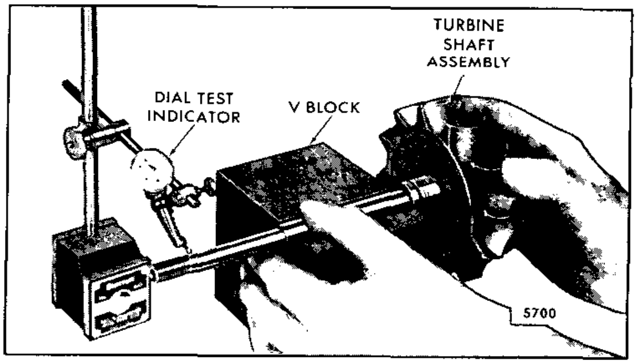


Fig. 12 – Measuring Concentricity Between Large and Small Turbine Shaft Diameters

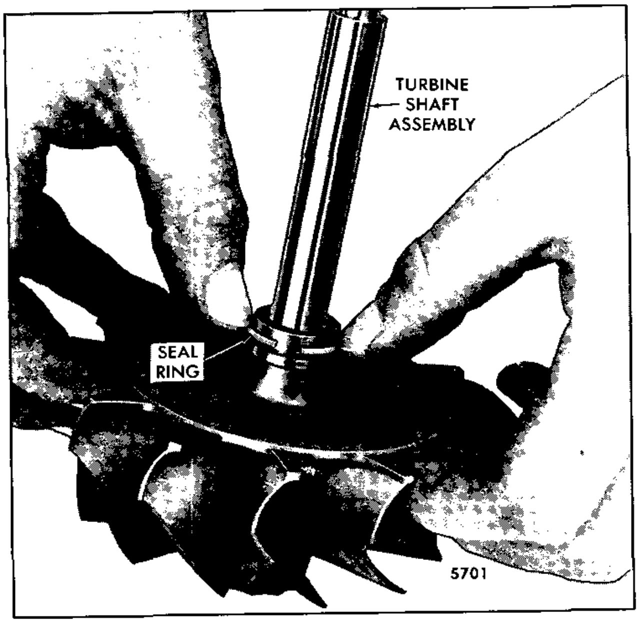


Fig. 13 – Installing Seal Ring on Turbine Shaft

The backplate has no attachment to the bearing housing. Its position is fixed when the bearing housing and turbine housing are clamped together.

4. Lubricate the piston ring area of the shaft and wheel assembly with clean engine oil and install it through the backplate and into the bearing housing (Fig. 15). *Be careful and avoid damage to the piston ring.*

5. Holding the end of the shaft, to prevent the shaft and wheel assembly from falling out of the bearing housing, install the assembly in the turbine housing wheel end down.

6. Lubricate the inner and outer diameter of the bearing. Then install the bearing down over the shaft and into the bearing housing bore.

7. Lubricate the thrust faces on both side of the thrust bearing and install the bronze side of the bearing over the shaft and groove pins, engaging the pins to the holes in the thrust bearing (Fig. 16).

8. Install the oil deflector on the thrust sleeve.

9. Lubricate a new piston ring and install it on the thrust sleeve. *Do not over expand the piston ring.*

10. Lubricate a new seal ring and install it in the groove on the insert.

11. Lubricate the thrust sleeve and install the small end into the hole of the insert from the concave side of the insert. Be careful to avoid damage to the piston ring.

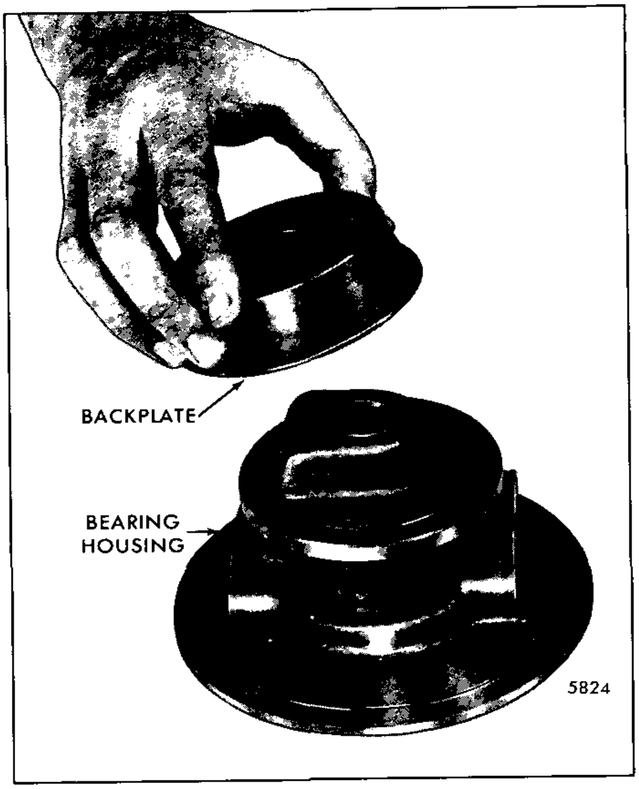


Fig. 14 – Assembling Bearing Housing, Gasket and Backplate

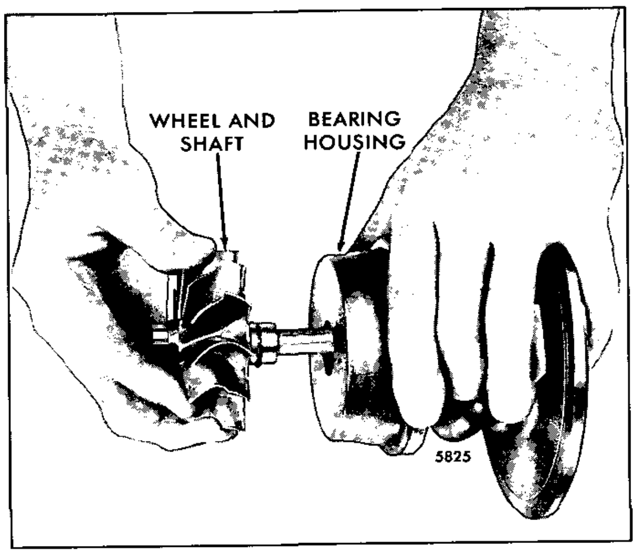


Fig. 15 – Installing Shaft and Wheel Assembly through Back Plate into Bearing Housing

12. Lubricate the thrust cavity in the bearing housing and install the insert, oil deflector and thrust sleeve assembly over the shaft and into the bearing housing

(Fig. 17). Align the oil deflector to mate with the oil drain cavity in the bearing housing.

NOTICE: It may be necessary to tap the insert with a soft hammer to seat it completely. Do not damage the seal ring.

13. Install the external snap ring in the compressor end cavity of the bearing housing. Be sure the ring seats fully in the groove, by twist–prying against the insert rim with a screw driver.

CAUTION: To prevent eye or facial injury, use a clean rag to snub the ring should it slip from the pliers during compression (Fig. 7).

14. Mount a dial indicator on the bearing housing with the stem resting on end of the shaft. Make sure that the turbine end of the bearing housing is properly seated in the turbine housing. Then move the shaft vertically to determine turbine wheel contour clearance. It must be .018″ to .049″. If the clearance is not within these tolerances, disassemble the unit to determine the cause. Look for burrs, dirt particles or incorrectly assembled parts. Reassemble and check the contour clearance. *If it is still out of tolerance, do not attempt to use.*

15. Install the compressor wheel on the shaft.

16. Lubricate the back face and threads of the lock nut with anti–seize compound. Install the lock nut on the shaft finger tight (until elastic of nut engages shaft threads) and place an 11/16″ socket on the turbine wheel lug to prevent the shaft from turning. Use a torque wrench to tighten the lock nut to 13 lb–ft (18 N·m) torque (Fig. 18).

17. Mount the dial indicator on the bearing housing with the stem resting on the end of the shaft to check end play. Total movement must be .002″ to .005″. If not within these tolerances, proceed as in Step 14 above.

18. Place the compressor cover on a work bench with the wheel cavity up. Lubricate the pilot diameter with grease or oil and place the rotating assembly in the compressor cover with the turbine wheel up.

19. Check the turbine wheel back clearance by placing two equal feeler gage stacks between the back face of the turbine wheel and the backplate on the opposite sides of the shaft (Fig. 19). Clearance must be .017″ to .049″. If clearance is not within limits, proceed as in Step 14 above.

20. Install four clamp plates and eight screw and lock washer assemblies. *Tighten the screws to 5 lb–ft (7 N·m) torque.* Use care not to overtighten the screws. *If the compressor cover needs to be reoriented upon installation on the engine, do not tighten the screws at this point.*

21. Turn the unit over and install it in the turbine housing. Apply anti–seize compound to the threads of the four screws. Install the two clamps, two lock plates and four screws. Tighten the screws to 12 lb–ft (16 N·m) torque.

22. Bend the tabs of the lock plates up against one flat of each screw. *If the turbine housing needs to be reoriented upon installation on the engine, do not tighten the screws or bend the lock plate tabs at this point.*

23. Inject approximately 1/4 ounce of clean engine oil into the oil inlet port of the bearing housing.

24. Spin the rotating assembly by hand to assure smooth and free rotation.

25. Seal the completed unit in a clean, dry plastic bag until installed on the engine.

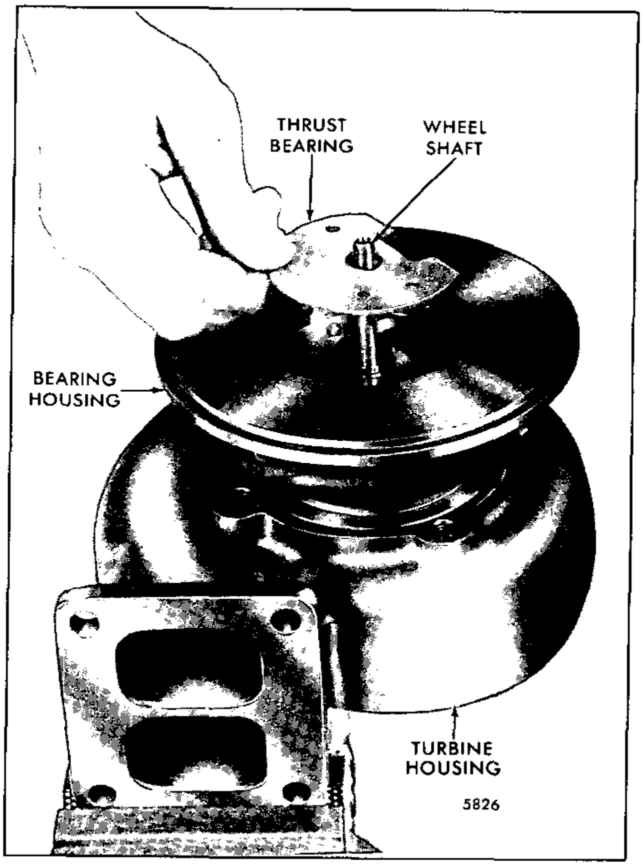


Fig. 16 – Install Thrust Bearing in Bearing Housing

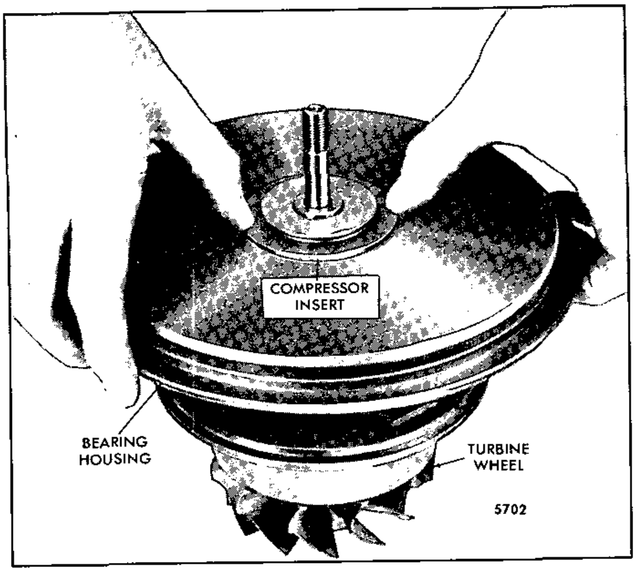


Fig. 17 – Installing Compressor Insert in Bearing Housing

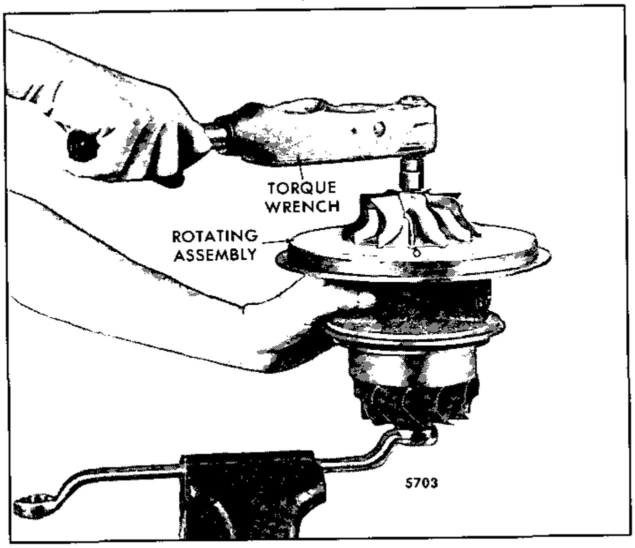


Fig. 18 – Tightening Compressor Locknut

Install Turbocharger

1. Inspect the intake and exhaust systems leading to the turbocharger to ensure absence of foreign material (even small particles can cause severe damage to the rotating assembly when inducted at high speeds).

2. Use *new* gaskets at all of the air, oil and exhaust connections to the turbocharger. *Do not use joint compound at the oil inlet and exhaust connections.*

3. Use anti–seize thread compound on all threaded fasteners used to mount the turbocharger.

4. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

5. Position the turbocharger so that it aligns with all corresponding connections on the engine.

6. Tighten the compressor housing and turbine housing clamp band retaining nuts to 10 lb–ft (14 N·m) torque.

7. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the brackets.

   When self locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self locking nuts on the bolts.

8. Slide the blower air inlet tube hose over the compressor housing outlet and secure it in place with hose clamps.

9. Tighten the turbocharger to exhaust manifold adaptor bolts securely.

10. Connect the oil inlet line to the cylinder block.

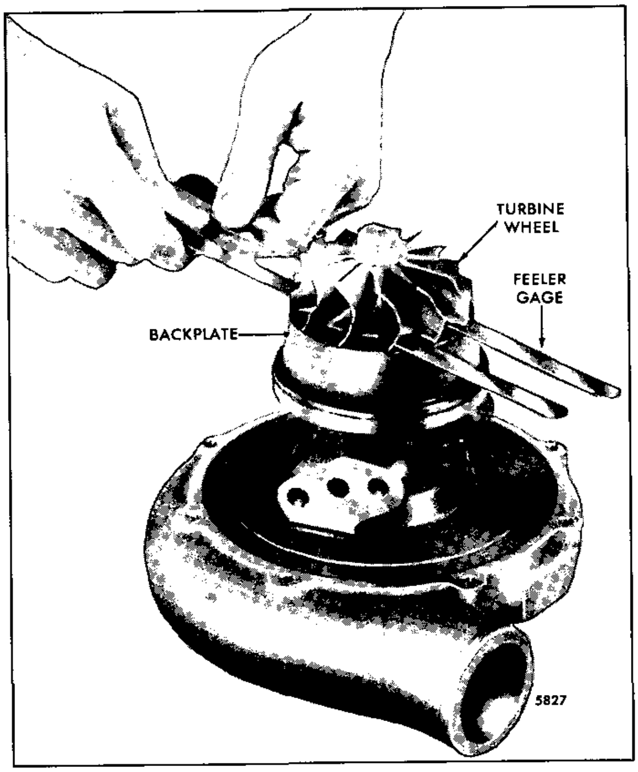


Fig. 19 – Checking Turbine Wheel to Backplate Clearance

11. After installing a rebuilt or new turbocharger, it is very important that all of the moving parts of the turbocharger center housing be lubricated as follows:

    a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing.

    b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

    c. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

    d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig – 69 kPa at idle speed).

    CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

    The free floating bearing in the turbocharger bearing housing requires positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed,* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearing can cause severe damage to the shaft and bearing of the turbocharger.

12. Check all connections, ducts and gaskets for leaks.

13. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, shut the engine down immediately and correct the cause.

NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER INTERCOOLER

The turbocharger intercooler is mounted on the air inlet side of the engine blower and is used to reduce the temperature of the compressed air from the turbocharger before the air enters the engine blower. This permits a more dense charge of air to be delivered to the engine. The cooling is accomplished by the raw water from the heat exchanger passing through the cells of the intercooler core. The compressed air enters the intercooler via the air inlet housing and circulates past the cooler core of the intercooler.

Remove Intercooler

1. Drain the raw water system.
2. Loosen the two hose clamps on the hose connecting the raw water inlet tube to the inlet end of the intercooler (Fig. 1).
3. Remove the four 5/16"–18 x 1" bolts and lock washers that retain the air inlet tube flange to the air inlet housing.
4. Disconnect the connection between the outlet end of the intercooler and the raw water discharge line.
5. Disconnect the manual shutdown, if used.
6. Remove the six bolts, nuts, washers and lock washers that retain the air inlet housing to the intercooler and remove the air inlet housing and the screen and gasket assembly.

   NOTICE: The bolts are not all the same length and their location should be noted during removal to facilitate installation.

7. Remove the six bolts and lock washers that retain the intercooler to the blower and remove the intercooler. Note the location of the two shorter bolts.
8. Remove the gasket from the side of the blower.

Clean Intercooler

Check all of the intercooler tubes to be sure they are free of obstructions.

If the tubes contain dirt or any other foreign material, they can be cleaned with a small brush or by use of a suitable solvent cleaning solution. Flush the core thoroughly with water to remove any foreign material and the solvent.

Install Intercooler

1. Affix a new gasket to the side of the blower.
2. Mount the intercooler assembly to the blower with the six bolts and lock washers and tighten the bolts to 16–20 lb–ft (22–27 N·m) torque.
3. Affix a new air inlet screen and gasket assembly on the intercooler.
4. Mount the air inlet housing to the intercooler with the six bolts, nuts, washers and lock washers and tighten the nuts to 35–39 lb–ft (47–53 N·m) torque.
5. Affix a new gasket on the air inlet housing flange and secure the air inlet tube flange to the air inlet housing with the four 5/16"–18 x 1" bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque.
6. Connect the raw water inlet tube to the inlet end of the intercooler with the hose and clamps. Tighten the clamps securely.
7. Connect the raw water discharge line to the outlet end of the cooler.
8. Connect the manual shutdown, if used.
9. Fill the raw water system. Then start the engine and check for air or water leaks.

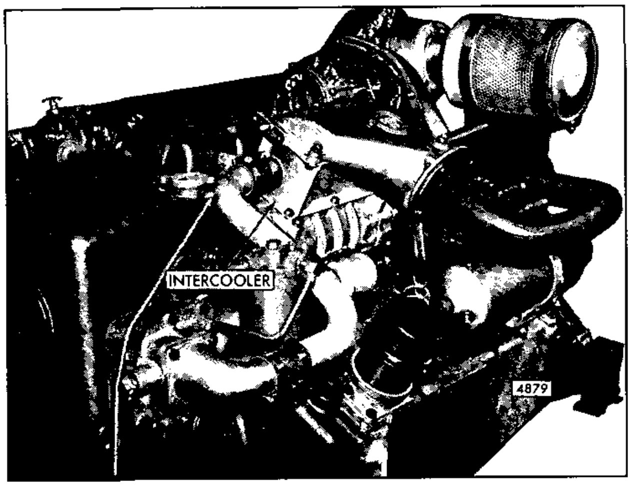


Fig. 1 – Turbocharger Intercooler Mounting

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

REWORKING BLOWER FRONT END PLATES - 6V-53 ENGINES

When rebuilding a 6V-53 blower assembly in the field, the front end plate can be reworked to provide improved lubrication, when desirable, in the area of the thrust washers. The rework procedure is as follows:

1. Remove the pipe plug from the horizontal oil gallery (B-B) of the end plate. Place a reamer in the chuck of the drill press and ream a .3070" - .3085" diameter hole 2.060" deep from the boss face (Fig. 1). Remove the metal cuttings from the hole.
2. Install the copper-plated dowel pin to the full depth of the reamed portion of the horizontal oil gallery.
3. Locate and mark the center of hole "A" (Fig. 5). The center of hole "A" is where the center line (B-B) of the horizontal oil gallery intersects with the center line (C-C) of the drain hole. Clamp the end plate on the bed of the press and center drill at the location marked. Then drill a 3/8" diameter hole 5/8" deep from the gasket face of the end plate. Lubricate the drill and the area of the end plate that is being reworked with mineral spirits or fuel oil.
4. Place either an end mill or a 3/4" counterbore reamer (remove the pilot from the reamer) in the chuck of the drill press and counterbore a 3/4" diameter hole 5/8" deep from the gasket face of the end plate.
5. Wash the end plate in clean fuel oil to remove the metal cuttings and dry it with compressed air.
   - **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**
6. Cut a piece of 3/8" I.D. Bundy tubing 2.00" long. Coat the tubing with Gasola or an equivalent type sealant. Press the tubing into the oil drain hole in the end plate flush to .010" below the edge of the plate. It is important that the area around the tube be oil tight.
7. Reinstall the pipe plug in hole (B-B).
8. When assembling the blower, apply a liberal amount of Lubriplate, or equivalent, on the surfaces of the thrust washers. This will provide lubrication of the thrust washers during initial start-up of the engine.

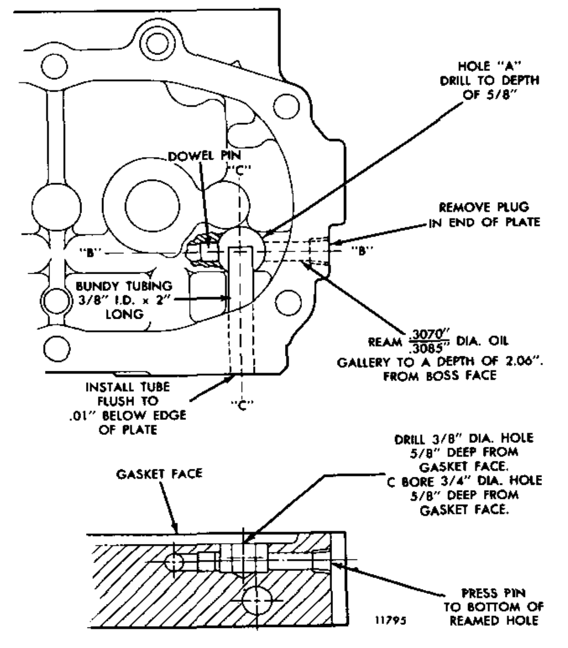


Fig. 1 - Dimensions for Reworking Front End Plate (6V-53 Engine)

TROUBLESHOOTING

TURBOCHARGER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
NOISY OPERATION OR VIBRATION	WHEEL SHAFT BEARINGS ARE NOT BEING LUBRICATED	Locate cause of loss of oil pressure and repair. Remove, dis-assemble and inspect turbocharger for bearing damage.
	IMPROPER CLEARANCE BETWEEN TURBINE WHEEL AND HOUSING	Remove, disassemble, and inspect turbocharger.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
ENGINE WILL NOT DELIVER RATED POWER	CLOGGED AIR INTAKE SYSTEM	Check air cleaner and clean air intake ducts.
	FOREIGN MATERIAL LODGED IN COMPRESSOR OR TURBINE WHEELS	Remove, disassemble and clean turbocharger.
	EXCESSIVE DIRT BUILD-UP IN COMPRESSOR	Thoroughly clean compressor assembly. Clean air cleaner and check for leaks.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
	ROTATING ASSEMBLY BEARING SEIZURE	Remove and overhaul turbocharger.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower			
Backlash — rotor gears (all)	.0005″	.0025″	.0035″
Backlash between upper rotor and camshaft or balance shaft gear (2–53 and 3–53)	.0030″	.0070″	
Backlash between blower drive gear and camshaft gear	.0030″	.0070″	
Oil seal (below end plate surface) (In–line and 6V–53)	.0020″	.0080″	
Oil seal (below end plate surface) (8V–53)	flush	.0100″	
Oil strainer (below end plate surface) (8V–53)	flush	.0150″	
Pin — Dowel (projection beyond inside face of front end plate) (8V–53)	.3800″		
Clearances:			
Thrust plate and thrust washer (In–line)	.0010″	.0030″	
Thrust plate and thrust washer (4–53T and 6V–53)	.0025″	.0050″	
Rotor to air outlet side of housing:			
In–Line and 6V–53	.0040″		
8V–53	.0050″		
3–53T	.0060″		
4–53T	.0070″		
Rotor to air inlet side of housing:			
In–Line	.0075″		
6V–53	.0100″		
3–53T	.0120″		
8V–53	.0170″		
Rotor to front end plate:			
In–Line	.0060″		
3–53T, 4–53T and 6V–53	.0080″		
+8V–53 (former)	.0070″		
6V–53T	.0100″		
†8V–53 (current)	.0170″		

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Rotor to rear (gear) end plate:			
2–53	.0060"		
3–53	.0080"		
4–53 and 3–53T	.0090"		
4–53T and 6V–53	.0100"		
6V–53T	.0120"		
+8V–53 (former)	.0140"		
†8V–53 (current)	.0070"		
Rotor-to-rotor clearance:			
In-line	.0100"		
3–53T	.0120"		
6V–53	.0090"		
6V–53T	.0130"		
Trailing edge of R.H. helix rotor to leading edge of L.H. helix rotor (8V–53)	.0080"		
Leading edge of R.H. helix rotor to trailing edge of L.H. helix rotor (8V–53)	.0180"		
Turbocharger (TE0675)			
Rotating shaft axial end play	.0040"	.0070"	
Rotating shaft radial movement	.0030"	.0070"	
Turbine wheel rotor shaft journal bearing:			
Inside diameter	.6268"	.6272"	
Outside diameter	.9780"	.9785"	
Turbine wheel shaft journal diameter	.6251"	.6254"	
Bearing bore diameter in center housing	.9827"	.9832"	
Turbocharger (T04B and TV61)			
Rotating shaft axial end play	.0040"	.0090"	
Rotating shaft radial movement	.0030"	.0070"	

+This clearance applies to former blowers with the ball bearings in the front end plate and roller bearings in the rear end plate.

†This clearance applies to current blowers with the roller bearings in the front end plate and ball bearings in the rear end plate.

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	260M BOLTS TORQUE N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	280M OR BETTER TORQUE N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE lb–ft	TORQUE N·m
Blower drive coupling-to-rotor gear bolt (In–line and 6V–53)	1/4–28	14–18	19–24
Blower drive gear pilot bolt (In–line and 6V–53)	5/16–24	25–30	34–41
Blower thrust washer retaining bolt (In–line and 6V–53)	5/16–24	25–30	34–41
Blower timing gear–to–rotor shaft bolts (In–line and 6V–53)	5/16–24	25–30	34–41
Air inlet adaptor-to-blower bolts	3/8–16	16–20	22–27
Air inlet housing-to-adaptor or blower housing bolts	3/8–16	16–20	22–27
Blower drive gear cover bolt	3/8–16	20–24	27–33
Blower drive support–to–blower rear end plate bolts	3/8–16	20–24	27–33
Blower–to–engine rear end plate and flywheel housing bolts (2–53 and 3–53)	3/8–16	20–25	27–34
Flywheel housing–to–blower drive support bolts	3/8–16	20–24	27–33
Front end plate cover bolts (4–53 and 6V–53)	3/8–16	20–25	27–34
Governor–to–blower front end plate bolts	3/8–16	20–24	27–33
Blower thrust washer retaining bolt (In–line and 6V–53)	3/8–24	54–59	73–80
Blower timing gear–to–rotor shaft bolts (8V–53)	3/8–24	50–55	68–75
Rotor shaft ball bearing retaining bolt (8V–53)	3/8–24	50–55	68–75
Blower end plate–to–block bolts	7/16–14	55–60	75–81
Rotor shaft ball bearing retaining nut (8V–53)	.781″–32	50–60	68–81

SERVICE TOOLS

TOOL NAME	TOOL NO.
Blower	
Blower clearance feeler gage set	J 1698–02
Blower drive cam installer	J 5209
Blower gear puller (part of J 23679)	J 28483
Blower service tool set (except 8V–53)	J 23679–A
Blower service tool set (8V–53)	J 21672
Handle	J 7079–2
Turbocharger	
Extension rod (2.500")	J 7057
Magnetic base indicator set	J 7872
Turbocharger inlet shield	J 26554–A

SECTION 4

LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

IN–LINE AND 6V–53 ENGINES

The engine lubrication systems, illustrated in Figs. 1 and 2, include an oil intake screen and tube assembly, an oil pump, an oil pressure regulator valve, a full flow oil filter with a bypass valve, an oil cooler and oil cooler bypass valve.

The rotor type oil pump is bolted to the back of the engine lower front cover and is driven directly by the crankshaft. The pump width varies for the In–line engines and the 6V–53 engine, but otherwise is of identical design. By rotating the pump 180°, it can be used for either right–hand or left–hand rotation engines.

Lubricating oil from the pump passes from the lower front engine cover through short gallery passages in the cylinder block. From the block, the oil flows to the full flow filter, then through the oil cooler and back into the front engine cover and cylinder block oil galleries for distribution to the various engine bearings. The drain from the cylinder head and other engine parts leads back to the oil pan.

Clean engine oil is assured at all times by the use of a replaceable element type full flow filter. With this type filter, which is installed between the oil pump and the oil cooler, all of the oil is filtered before entering the engine. Should the filter become plugged, the oil will flow through a bypass valve, which opens at approximately 18–21 psi (124–145 kPa) directly to the oil cooler. Bypass filters are used in certain applications when additional filtration is required (Section 4.2).

On current engines, the oil cooler bypass valve is located on the right–hand side of the engine front cover and the oil pressure regulator valve is located on the left–hand side as viewed from the rear of the engine (Figs. 1 and 2). On former engines, both valves were located on the right–hand side of the cover (Figs. 1 and 2).

If the cooler becomes plugged, the oil flow will be to a bypass valve in the lower engine front cover and then to the cylinder block oil galleries. The bypass valve opens at approximately 52 psi (359 kPa) in the current In–line engines and 6V–53 engines. In the former In–line engines, the bypass valve opens at approximately 30 psi (207 kPa).

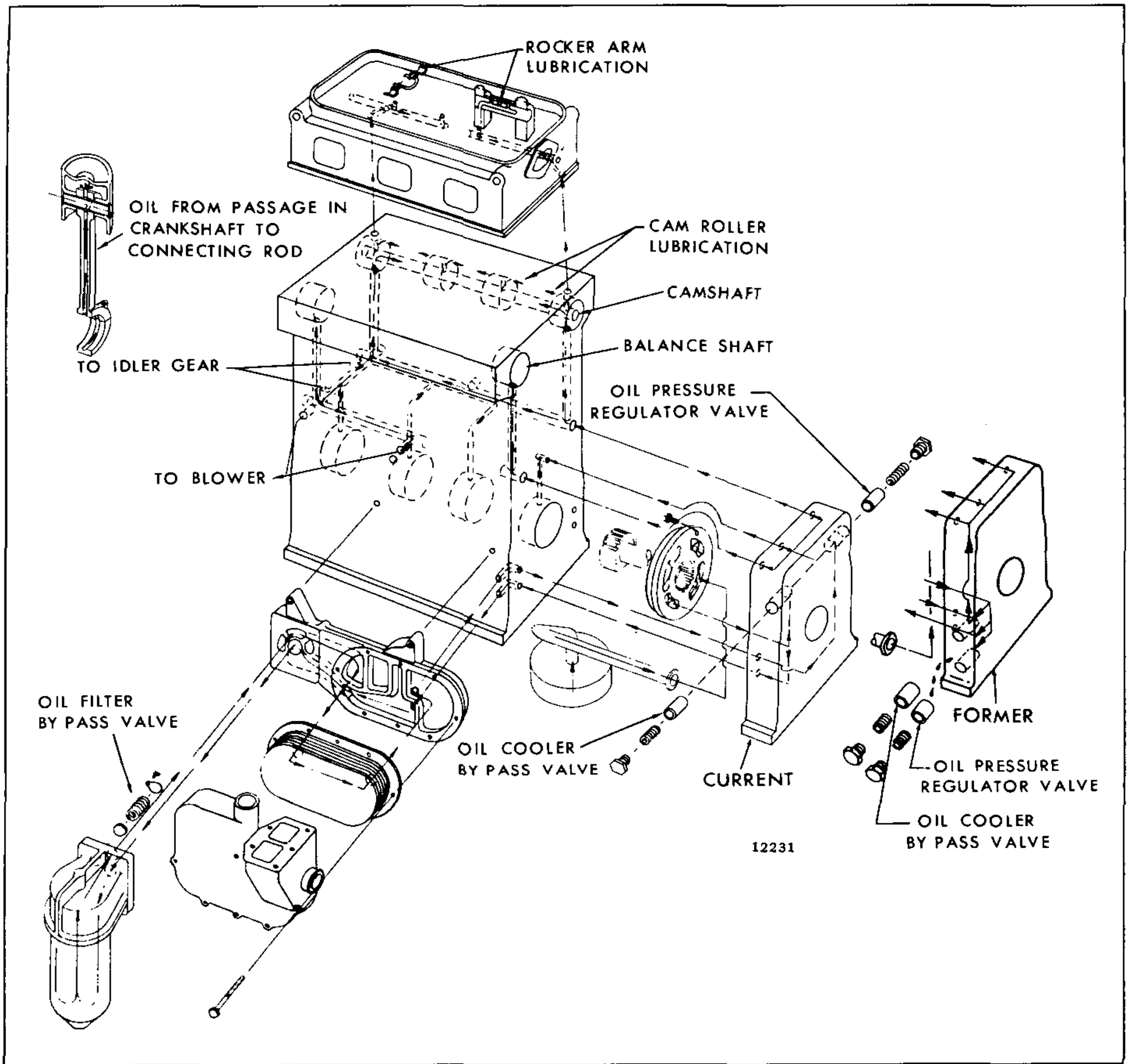


Fig. 1 – Schematic Diagram of Typical In–line Engine Lubrication System

The bypass valve opens at approximately 32 psi (221 kPa) on 6V–53 marine engines prior to engine number 6D–11074 and all 6V–53 engines prior to engine number 6D–17960.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located in the lower front engine cover. The regulator valve, located in the pump outlet passage, opens at the pressure shown in the Table in Section 4.1.1 and returns excess oil directly to the crankcase.

Lubricating Oil Distribution

Oil from the oil cooler on the In–line engine is directed to the lower engine front cover and then to a longitudinal main oil gallery in the cylinder block. This gallery distributes the oil, under pressure, to the main bearings and to a horizontal transverse passage at one end of the block and to

vertical passages at each corner of the block which provide lubrication for the balance shaft and camshaft bearings (Fig. 1). The camshaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

On a 6V–53 engine, oil from the pump enters a passage in the cylinder block and flows under pressure to the filter and oil cooler and returns through a passage in the block to the lower engine front cover. From a passage in the cover, the oil flows to the longitudinal main oil gallery in the block which distributes the oil, under pressure, to the main bearings. Oil passages branching off from the main oil gallery direct oil to the camshaft end bearings, idler gear and accessory drive gear bearings, blower, and cylinder heads.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. All of the camshaft bearings incorporate small slots through which lubricating oil is directed at the cam follower rollers.

Oil for lubricating the connecting rod bearings, piston pins, and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the bearings of the camshafts, balance shaft (In-line engine), idler gears and accessory drive gears (6V–53 engine).

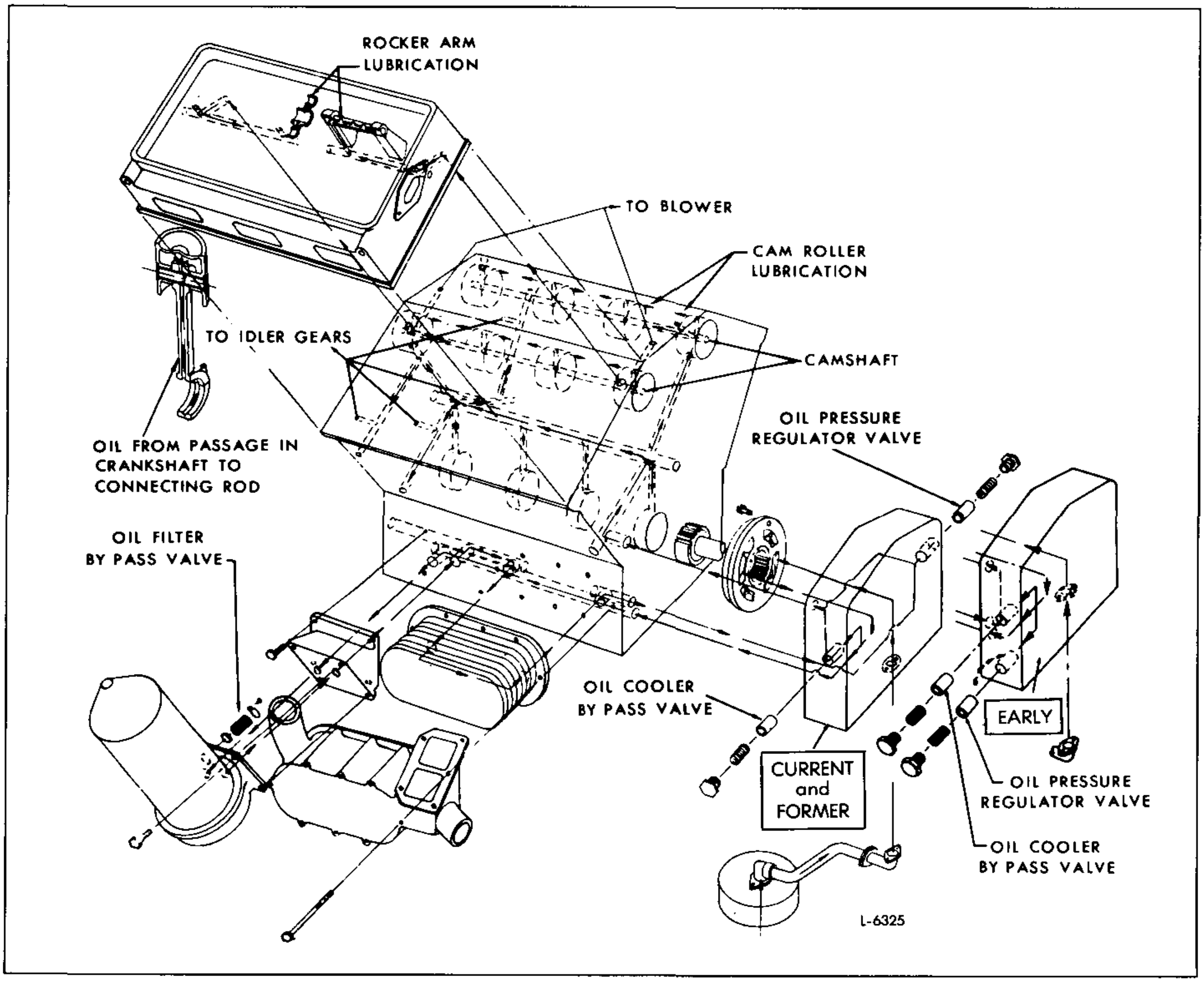


Fig. 2 – Schematic Diagram for 6V–53 Engine Lubrication System

Drilled oil passages on the camshaft side of the cylinder head (Figs. 1 and 2) are supplied with oil from the bores located at each end of the cylinder block. Oil from these drilled passages enters the drilled rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker arm bearings and push rod clevis bearings.

Excess oil from the rocker arms lubricates the lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes at each end of the cylinder block and then through the flywheel housing and front cover to the crankcase.

The blower bearings are pressure lubricated by oil from drilled passages in the cylinder block which connect matching passages in the blower end plates which, in turn, lead to the bearings. On current 6V–53 engines (built Jan. 77 and after) the lubricating oil is supplied from the main oil gallery to the right rear camshaft bushing (Fig. 2). This oil is forced through an oil passage in the camshaft and lubricates all camshaft bushings on the right bank as well as the blower. The left front bank camshaft bushing is supplied pressurized oil directly from the main oil gallery (Fig. 2). This oil then flows through the left bank camshaft and lubricates all left bank camshaft bushings as well as the blower. On former engines, the blower bearings received lubrication indirectly via the right rear camshaft end bearing only. Excess oil returns to the crankcase via drain holes in the blower end plates which lead to corresponding drain holes in the cylinder block (In–line engines) or the governor housing (6V–53 engines).

The blower drive gear hub in a 6V–53 engine is pressure lubricated through a connecting passage from the rear blower end plate, through the governor housing and into the blower and governor drive support.

Four tapped oil pressure take–off holes (three at the rear and one at the front) are provided in a 6V–53 cylinder block.

One tapped oil pressure take–off hole is provided in the lower engine front cover on some In–line engines. In addition, tapped oil holes in the cylinder block, on the side opposite the blower, are also provided as follows: three holes in the four–cylinder block and two holes in the three–cylinder block when the blower is on the left side of the engine or three holes when the blower is on the right side of the engine.

Lubricating System Maintenance

Use the proper viscosity grade and type of *heavy duty* oil as outlined in the *Lubrication Specifications* in Section 13.3. Change the oil and replace the oil filter elements at the periods recommended by the oil supplier (based on his analysis of the drained engine oil) to ensure trouble–free lubrication and longer engine life.

The oil level should never be allowed to drop below the *low* mark on the dipstick. Overfilling the crankcase may contribute to abnormal oil consumption and result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time (approximately ten minutes) allowed for the oil to drain back from the various parts of the engine. If more oil is required, add only enough to bring it to the proper level on the dipstick.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to Section 5 for the recommended cleaning procedure.

Detection of Lube Oil Leaks

Detroit Diesel uses red dye to detect lube oil system leaks during engine test. Customers receiving new engines may notice some residual dye remaining in their lube oil systems. This dye should be quickly dispersed after the first few hours of engine oepration.

8V–53 ENGINE

The 8V–53 engine lubrication system, illustrated in Fig. 3, includes an oil intake screen and tube assembly, an oil pump with a an oil pump with a relief valve, an oil pressure regulator valve, a full flow oil filter with a bypass valve, an oil cooler and an oil cooler bypass valve.

The oil is circulated by a gear–type oil pump mounted on the number 4 and 5 main bearing caps and is driven by the crankshaft timing gear.

Lubricating oil is drawn by suction from the oil pan through the inlet screen and pipe to the pump where it is pressurized. The oil then passes from the pump to a gallery in the cylinder block, to the full–flow filter adaptor, through the filter, then through the oil cooler and into the engine front cover and cylinder block oil galleries for distribution to the various engine bearings, including the outboard bearing in the front cover. The oil drains from the cylinder head and other engine parts back to the oil pan.

A spring–loaded relief valve, located in the oil pump outlet pipe, bypasses excess oil back into the crankcase when the engine is cold or when the pressure in the engine oil gallery exceeds approximately 120 psi (827 kPa).

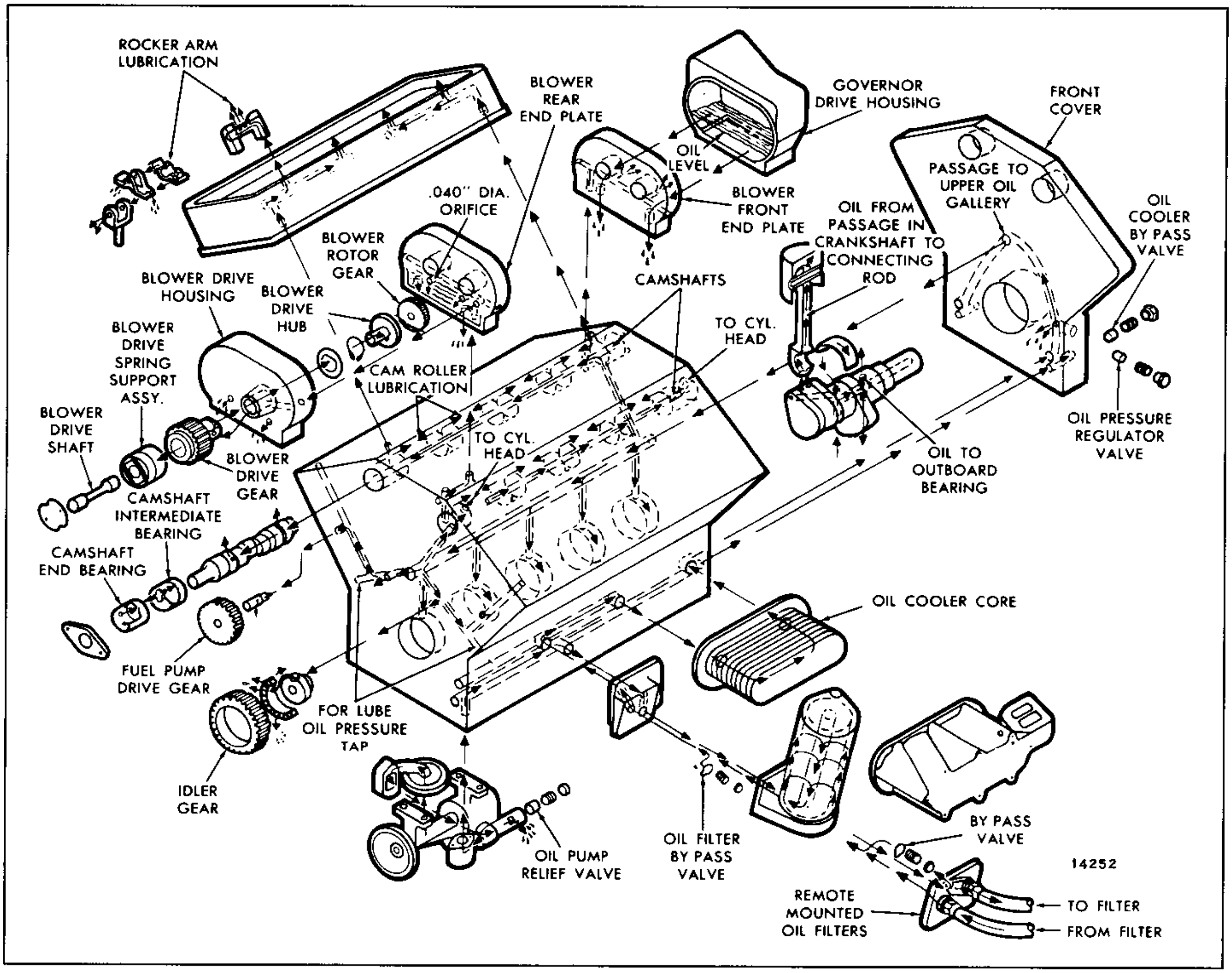


Fig. 3 – Schematic Diagram of Typical 8V–53 Engine Lubrication System

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of an oil pressure regulator valve in the engine front cover which opens at approximately 52 psi (359 kPa).

Clean engine oil is assured at all times by the use of a replaceable element type full–flow filter which is installed between the oil pump and the oil cooler. All of the oil is filtered before entering the engine. Should the filter become plugged or before the engine is at operating temperature, the oil will flow through a bypass valve, which opens at approximately 18–21 psi (124–145 kPa), directly to the oil cooler.

The oil cooler bypass valve, which opens at approximately 52 psi (359 kPa), is located in the engine front cover. If the cooler becomes clogged or before the engine reaches operating temperature, the oil flow will be to the bypass valve, then through the engine front cover oil passage and the cylinder block oil galleries.

Lubricating Oil Distribution

Oil from the pump enters a passage in the cylinder block and flows under pressure to the filter and oil cooler, then through a passage in the cylinder block to the engine front cover. From a passage in the cover, the oil flows to the longitudinal main oil gallery which distributes the oil, under pressure, to the main bearings and the outboard bearing. Oil passages branching off from the main oil gallery direct oil to the camshaft end bearings, idler gear and fuel pump drive gear bearings, blower and cylinder heads.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. All of the camshaft bearings incorporate small slots

through which lubricating oil is directed to the cam follower rollers.

Oil for lubricating the connecting rod bearings, piston pins, and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pockets through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the camshaft end bearings, idler gear, and fuel pump drive gear.

Drilled oil passages on the camshaft side of the cylinder heads are supplied with oil from the bores located at each end of the cylinder block (Fig. 3). Oil from these drilled passages enters the drilled rocker shaft brackets at the lower ends of the drilled bolts, and lubricates the rocker arm bearings and push rod shaft clevis bearings.

Excess oil from the rocker arms lubricates the lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes at each end of the cylinder block and then drains back through the flywheel housing and front cover to the crankcase.

Oil is forced through drilled oil passages in the cylinder block to the blower. The oil level in the blower and the governor drive is maintained by two .040" diameter orifices in the blower end plates. Thus, the rotor timing gears and the governor weights turn in oil.

The splash of the oil and the vapor created lubricate the blower bearings and supplies oil to the blower drive gear, spring pack and drive shaft. Oil is returned to the blower drive support by a groove in the drive gear hub. Excess oil helps lubricate the gear train before returning to the crankcase. Two tapped oil pressure take–off holes are located at the rear of the cylinder block.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to Section 5 for the recommended cleaning procedure.

OIL PRESSURE TAKE-OFF LOCATIONS

The cylinder block illustrations in Fig. 4 show the main oil gallery pressure locations that are available for supplying oil under pressure to oil gages, Jacobs engine brake or other accessories.

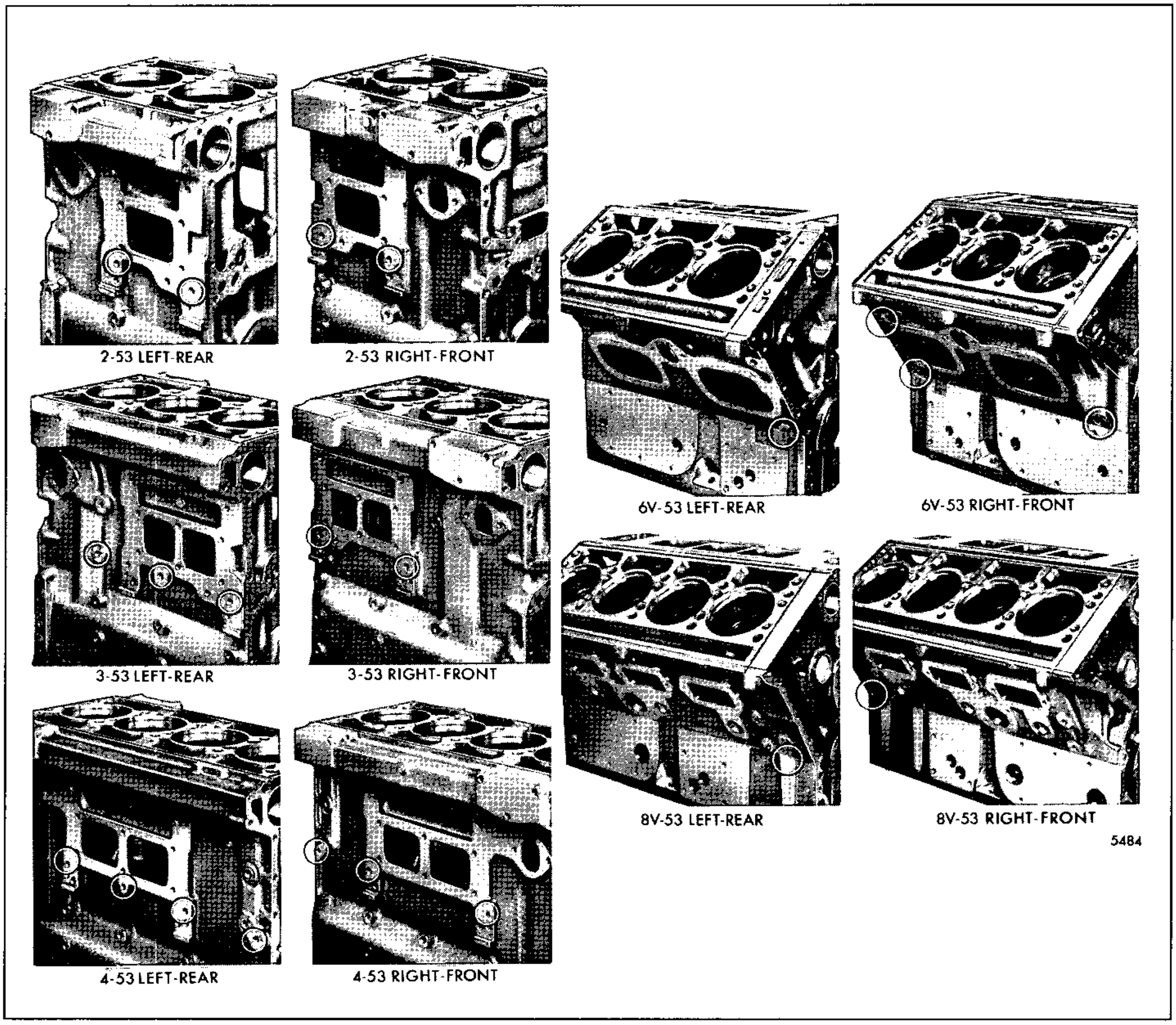


Fig. 4 – Oil Pressure Take-Off Locations

LUBRICATING OIL PUMP

IN–LINE AND 6V ENGINES

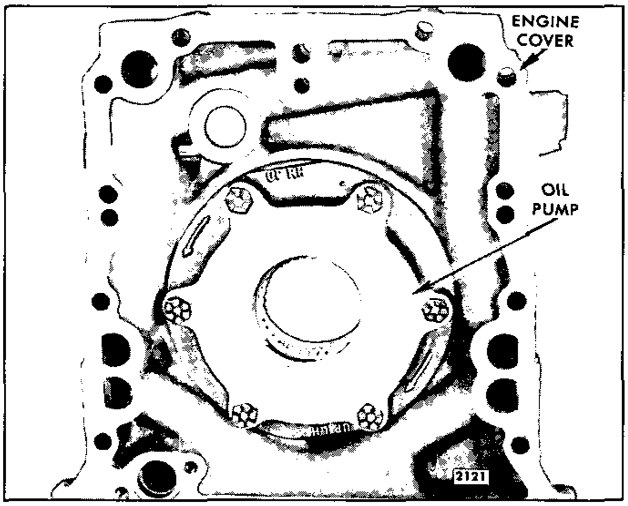


Fig. 1 – Typical Right–Hand Rotation Oil Pump Mounting

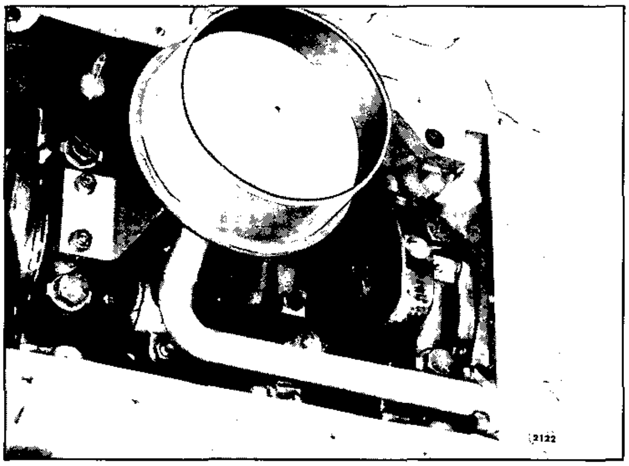


Fig. 2 – Typical Oil Pump Inlet Pipe and Screen Mounting

The lubricating oil pump, assembled to the inside of the lower engine front cover as illustrated in Fig. 1, is of the rotor type in which the inner rotor is driven by a gear pressed on the front end of the crankshaft. The outer rotor is driven by the inner rotor. The bore in the pump body, in which the outer rotor revolves, is eccentric to the crankshaft and inner rotor. Since the outer rotor has nine cavities and the inner rotor has eight lobes, the outer rotor revolves at eight–ninths crankshaft speed. Only one lobe of the inner rotor is in full engagement with the cavity of the outer rotor at any given time, so the former can revolve inside the latter without interference.

The pump width varies for the 2, 3 and 4 cylinder In–line and 6V–53 engines, but otherwise is of identical design. By rotating the pump 180°, it can be used for either a right–hand or left–hand rotation engine.

The 3, 4 and 6V–53 turbocharged engines use a higher capacity oil pump (which includes thicker inner and outer rotors) than the naturally aspirated engines.

Operation

As the rotors revolve, a vacuum is formed on the inlet side of the pump and oil is drawn from the crankcase, through the oil pump inlet pipe and a passage in the front cover, to the inlet port and then into the rotor compartment of the pump. Oil drawn into the cavities between the inner and outer rotors on the inlet side of the pump is then forced out under pressure through the discharge port into a passage in the front cover, which leads to the lubricating oil filter and cooler, and is then distributed throughout the engine.

If a check of the lubrication system indicates improper operation of the oil pump, remove and disassemble it as outlined below.

Remove Oil Pump

1. Drain the oil from the engine.
2. Remove the crankshaft pulley, fan pulley, support bracket and any other accessories attached to the front cover.
3. Remove the oil pan.
4. Refer to Fig. 2 and remove the four bolts which attach the oil pump inlet pipe and screen assembly to the main bearing cap and engine front cover or oil pump inlet elbow. Slide the flange and the seal ring on the inlet pipe and remove the pipe and screen as an assembly. Remove the oil pump inlet elbow (if used) and gasket from the engine front cover.
5. Remove the lower engine front cover.
6. Remove the six bolts and lock washers (if used) which attach the pump assembly to the engine front cover and withdraw the pump assembly from the cover (Fig. 1).

Disassemble Oil Pump

If the oil pump is to be disassembled for inspection or reconditioning, proceed as follows:

1. Refer to Fig. 5 or 6 and remove the two drive screws holding the pump cover plate to the pump body. Withdraw the cover plate from the pump body.

2. Remove the inner and outer rotors from the pump housing.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

The greatest amount of wear in the oil pump is imposed on the lobes of the inner and outer rotors.

This wear may be kept to a minimum by using clean oil. If dirt and sludge are allowed to accumulate in the lubricating system, excessive rotor wear may occur in a comparatively short period of time.

Inspect the lobes and faces of the pump rotors for scratches or burrs and the surfaces of the pump body and cover plate for scoring. Scratches or score marks may be removed with an emery stone.

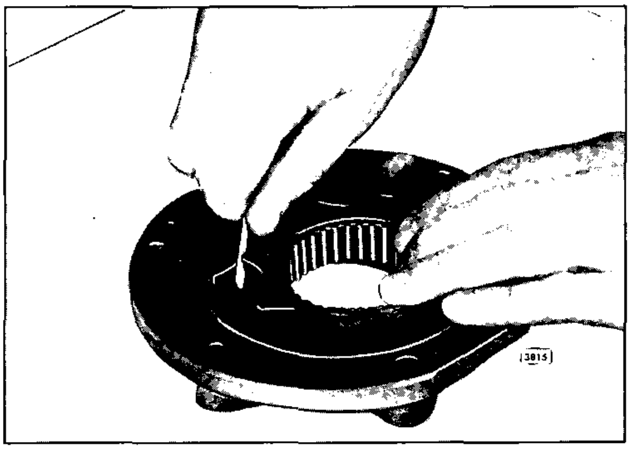


Fig. 3 – Measuring Rotor Clearance

Measure the clearance between the inner and outer rotors at each lobe (Fig. 3). The clearance should not be less than .0005" or more than .011". Measure the clearance from the face of the pump body to the side of the inner and outer rotor with a micrometer depth gage (Fig. 4). The clearance should not be less than .001" or more than .0035".

Inspect the splines of the inner rotor and the oil pump drive gear. If the splines are excessively worn, replace the parts. The rotors are serviced as matched sets, therefore, if one rotor needs replacing, replace both rotors.

Remove the oil inlet screen from the oil inlet pipe and clean both the screen and the pipe with fuel oil and dry them with compressed air. Replace the inlet pipe flange seal ring with a new seal ring.

Assemble Oil Pump

After the oil pump parts have been cleaned and inspected, refer to Fig. 5 or 6 and assemble the pump as follows:

1. Lubricate the oil pump outer rotor with engine oil and place it in the pump body.
2. Lubricate the oil pump inner rotor with engine oil and place it inside of the outer rotor.
3. Place the cover plate on the pump body and align the drive screw and bolt holes with the holes in the pump body. Since the holes are offset, the cover plate can be installed in only one position.
4. Install two new drive screws to hold the assembly together.

Remove Pump Drive Gear from Crankshaft

With the lower engine front cover and the lubricating oil pump removed from the engine, the oil pump drive gear may, if necessary, be removed from the end of the crankshaft as follows:

1. Thread the crankshaft pulley retaining bolt in the end of the crankshaft (Fig. 7).

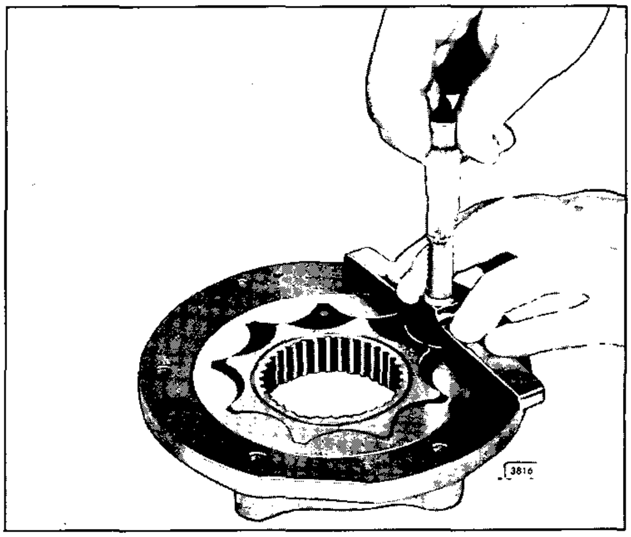


Fig. 4 – Measuring Clearance from Face of Pump Body to Side of Rotor

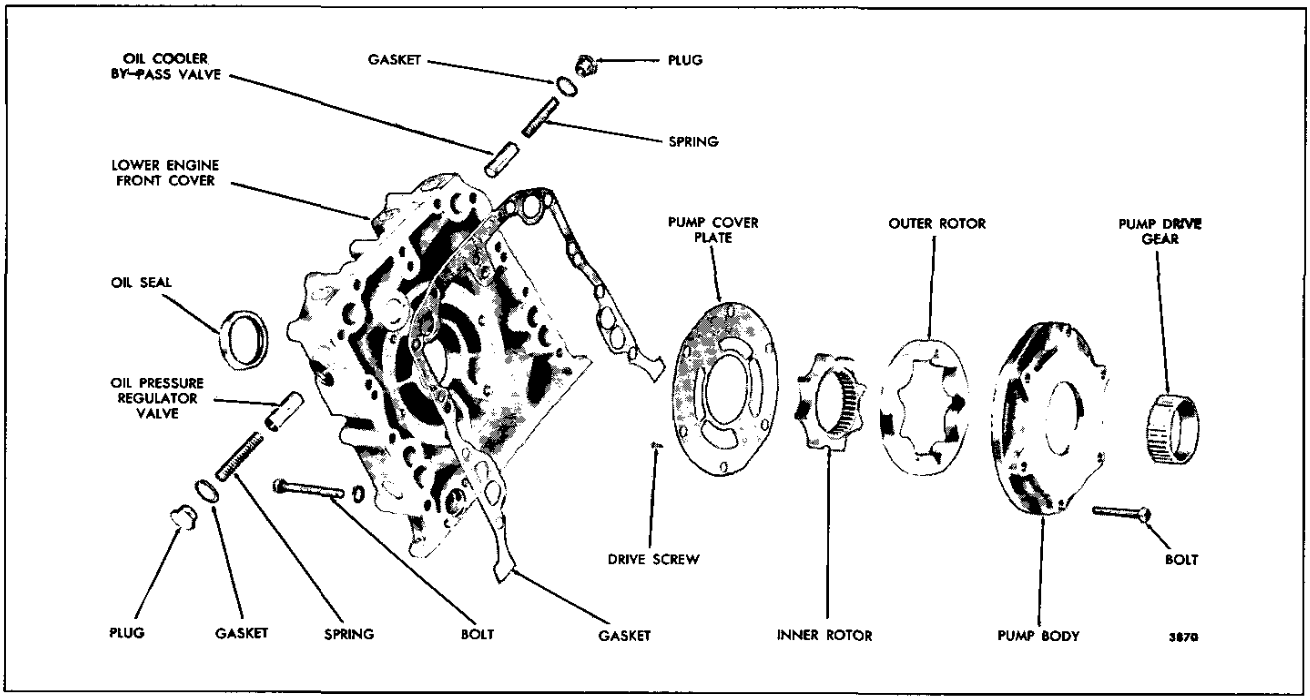


Fig. 5 – Oil Pump Details and Relative Location of Parts (Current)

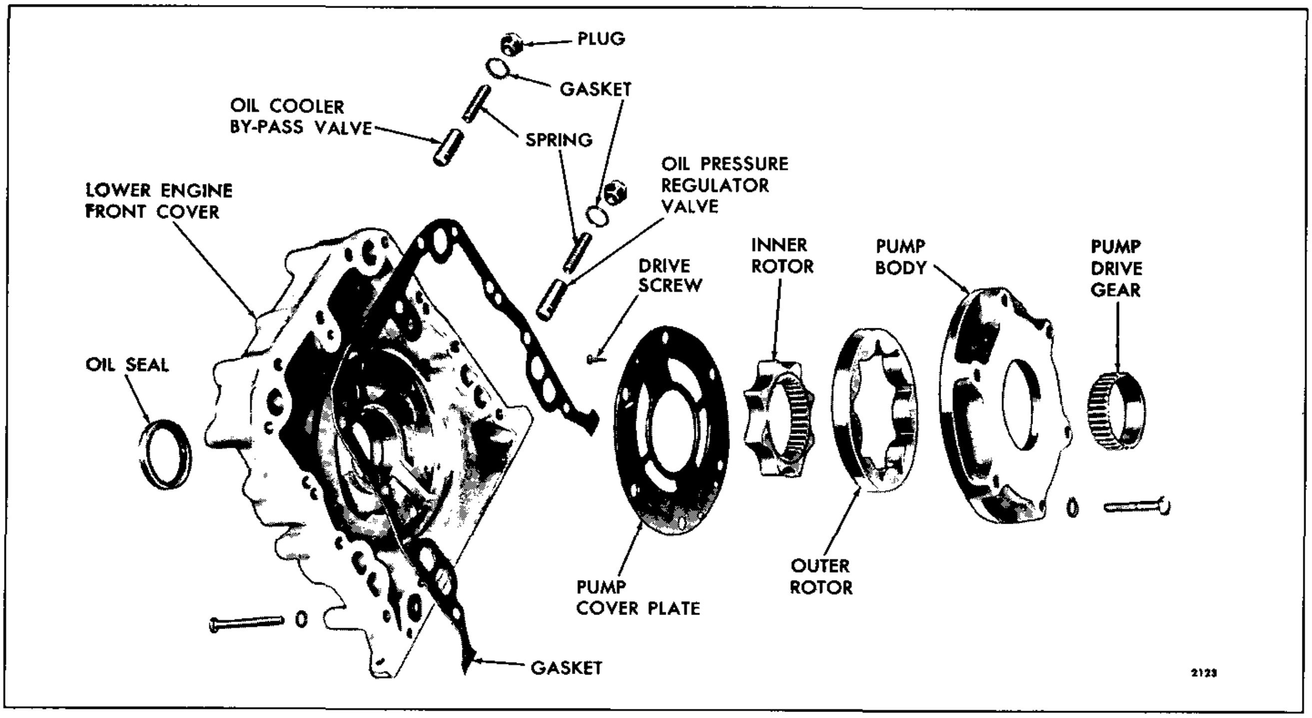


Fig. 6 – Oil Pump Details and Relative Location of Parts (Former)

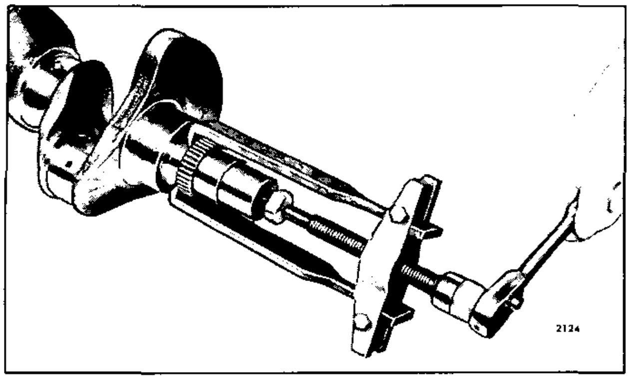


Fig. 7 - Removing Oil Pump Drive Gear

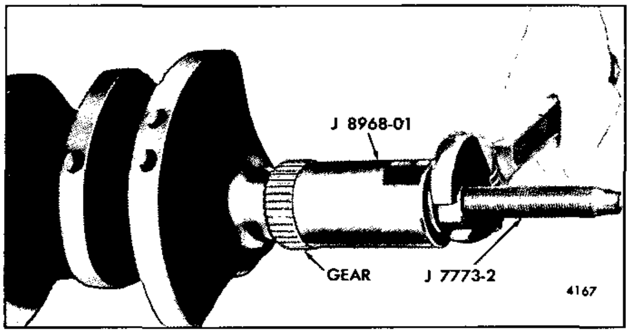


Fig. 8 - Installing Oil Pump Drive Gear Using Tools J 8968-01 and J 7773-2

2. Attach the jaws of a suitable gear puller behind the gear and locate the end of the puller screw in the center of the pulley retaining bolt.

3. Turn the puller screw clockwise to remove the gear from the crankshaft.

Install Pump Drive Gear on Crankshaft

1. Lubricate the inside diameter of a new oil pump drive gear with engine oil. Then, start the gear straight on the crankshaft with the chamfered edge of the gear toward the butt end of the crankshaft. Reinstallation of a used gear is not recommended.

2. Position the drive gear installer J 8968-01 over the end of the crankshaft and against the drive gear and force the gear in place (Fig. 8). When the end of the bore in the tool contacts the end of the crankshaft, the drive gear is correctly positioned (2.680" from the front end of the crankshaft to the forward face of the gear).

3. It is important that the press fit of the drive gear to the crankshaft be checked to be sure that the gear does not slip on the crankshaft. It is recommended that the press fit (slip torque) be checked with tool J 23126. On in-line or 6V engines, the drive gear should not slip on the crankshaft at 100 lb-ft (136 N·m) torque. *Do not exceed this torque. If the gear slips on the shaft, another oil pump drive gear should be installed.*

Install Oil Pump

1. The markings on the pump body indicate the installation as pertaining to left or right-hand crankshaft rotation. Be sure that the letters "UP R.H." (right-hand rotation engine) or "UP L.H." (left-hand rotation engine) on the pump body are at the top (Fig. 1).

2. Insert the six bolts with lock washers (if used) through the pump body and thread them into the engine front cover. Tighten the bolts to 13-17 lb-ft (18-23 N·m) torque.

3. Install the lower engine front cover and pump assembly on the engine as outlined in Section 1.3.5.

4. Attach the oil inlet screen to the oil inlet pipe support with two locknuts (6V engine) or two bolts and lock washers (Fig. 9).

5. Use a new gasket and attach the oil pump inlet elbow (6V engine) to the underside of the engine front cover with the two bolts and lock washers.

6. Place the oil pump inlet pipe and screen assembly in position and fasten the support to the main bearing cap with the two bolts and lock washers.

7. Slide the inlet pipe flange and seal ring against the engine front cover (or oil pump inlet elbow on the 6V engine) and secure them with the two bolts and lock washers.

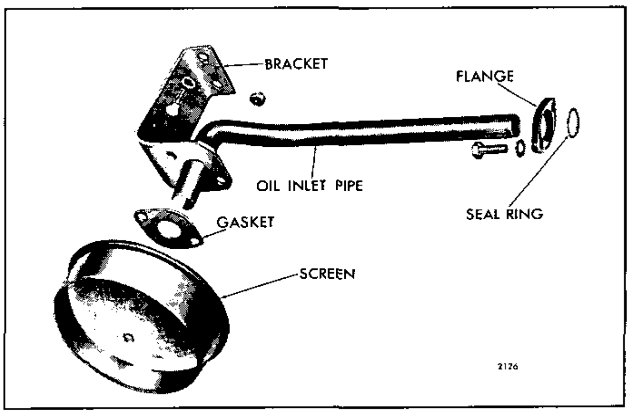


Fig. 9 - Oil Pump Inlet Pipe and Screen Details and Relative Location of Parts (In-Line Engine)

On In–line engines, the oil pump inlet tube and water bypass tube seals are the same size but of different material. *Be sure that the correct seal is used.* A new oil pump inlet tube seal may be identified by its white stripe.

8. Install the oil pan and refill the crankcase to the proper level.

9. Install the crankshaft pulley, fan pulley, support bracket and any other accessories that were attached to the front cover.

8V ENGINE

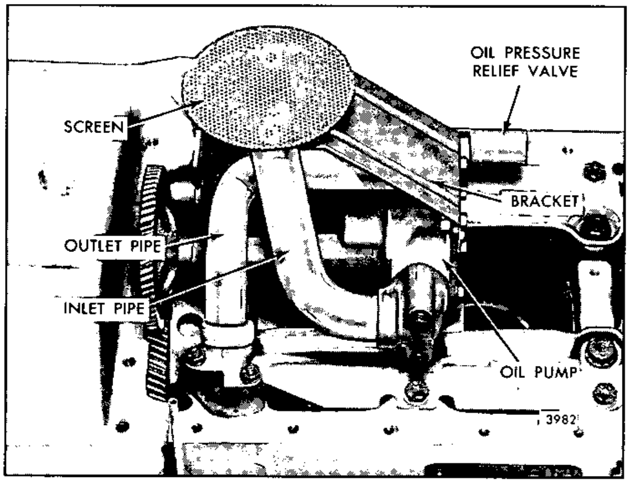


Fig. 10 – Lubricating Oil Pump Mounting (8V Engine)

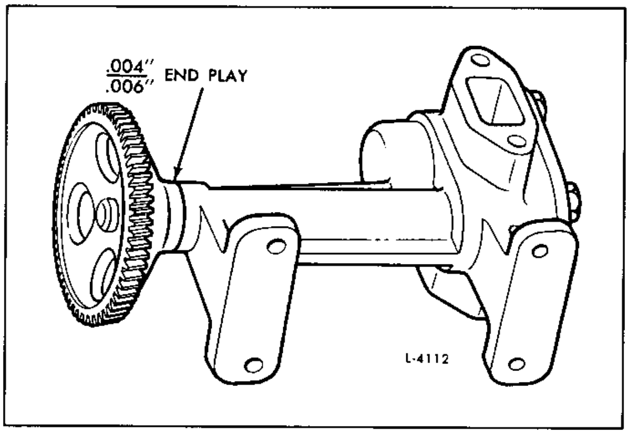


Fig. 11 – Oil Pump Gear End Play

The oil pump (Fig. 10) on an 8V engine is mounted on the No. 4 and No. 5 main bearing caps. The oil pump is driven by the crankshaft timing gear.

A spring–loaded relief valve, which is located in the oil pump outlet pipe assembly, bypasses excess oil back to the crankcase when the pressure in the engine oil gallery exceeds approximately 120 psi (827 kPa).

Effective with engine 8D–174, a new lubricating oil pump and inlet tube is used on the 8V engine. The pump has a new cover which supports the ends of the drive and driven shafts. The new drive shaft is longer and larger in diameter and the new drive gear has a larger inside diameter. When replacing an old oil pump with a new pump on an engine that has the inlet tube assembled to the pump cover, it will be necessary to install a new oil pump inlet system.

Effective with engine 8D–4611, a new high capacity oil pump with longer drive and driven gears is used on the 8V engines. The high capacity pump must be used in combination with the seven hole upper main bearing shells (Section 1.3.4). The new pump can be used with the former one hole upper main bearing shells.

Remove Oil Pump

1. Remove the bolts and lock washers securing the inlet pipe and the bracket to the oil pump. Then remove the inlet pipe, screen and bracket as an assembly from the pump.

2. Remove the two bolts and lock washers securing the oil pressure relief valve to the oil pump.

3. Remove the oil pump outlet pipe–to–cylinder block bolts. Then, remove the relief valve and outlet pipe as an assembly from the engine.

4. Remove the oil pump–to–bearing cap attaching bolts and lock washers and remove the pump assembly from the engine.

   NOTICE: Shims are used between the oil pump mounting feet and the main bearing caps. Whenever the original pump from such an engine is reinstalled, the same shims or an equal number of new (identical) shims must be placed under both the front and rear mounting feet and the number then adjusted to obtain the proper clearance between the gears.

Disassemble Oil Pump

Remove the four bolts and lock washers and pull the cover off of the shafts. Slide the pump gear from the pump cavity.

Remove the oil pump driven gear by pressing the drive shaft through the gear.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

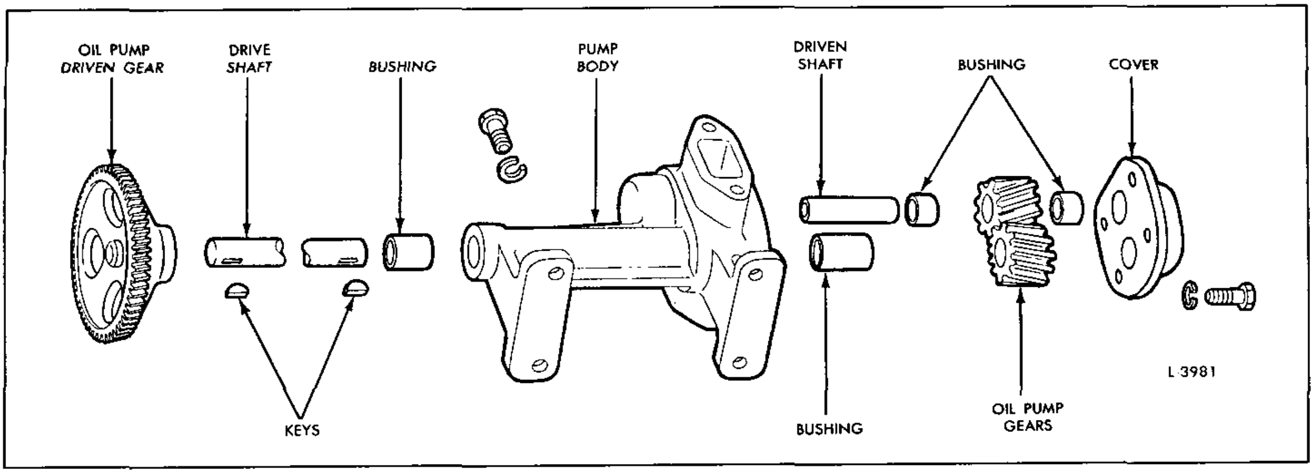


Fig. 12 – Lubricating Oil Pump Details and Relative Location of Parts (8V Engine)

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. This wear may be kept to a minimum by keeping the lubricating oil clean and acid–free. If dirt and sludge are allowed to accumulate in the lubricating system, pronounced gear wear may occur in a comparatively short period of time. Proper servicing of oil filters will increase the life of the gears.

Examine the internal gear cavity of the pump body and scavenger pump, if used, for wear or scoring. Also, inspect the pump cover, or the spacer between the pump and scavenger bodies, for wear. Replace parts, if necessary.

Inspect the bushings in the pump body and cover (or scavenging pump body). If the bushings are worn excessively, replace the pump and cover (or scavenging pump body) unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings in the pump bodies. The bushings must be located and positioned as shown in Fig. 13. Also, the gear bore and the bushing bore in both the pump body and scavenging pump body must be concentric within .001" total indicator reading. The shaft–to–cover or scavenging pump body to bushing clearance with new parts is .001" to .0027".

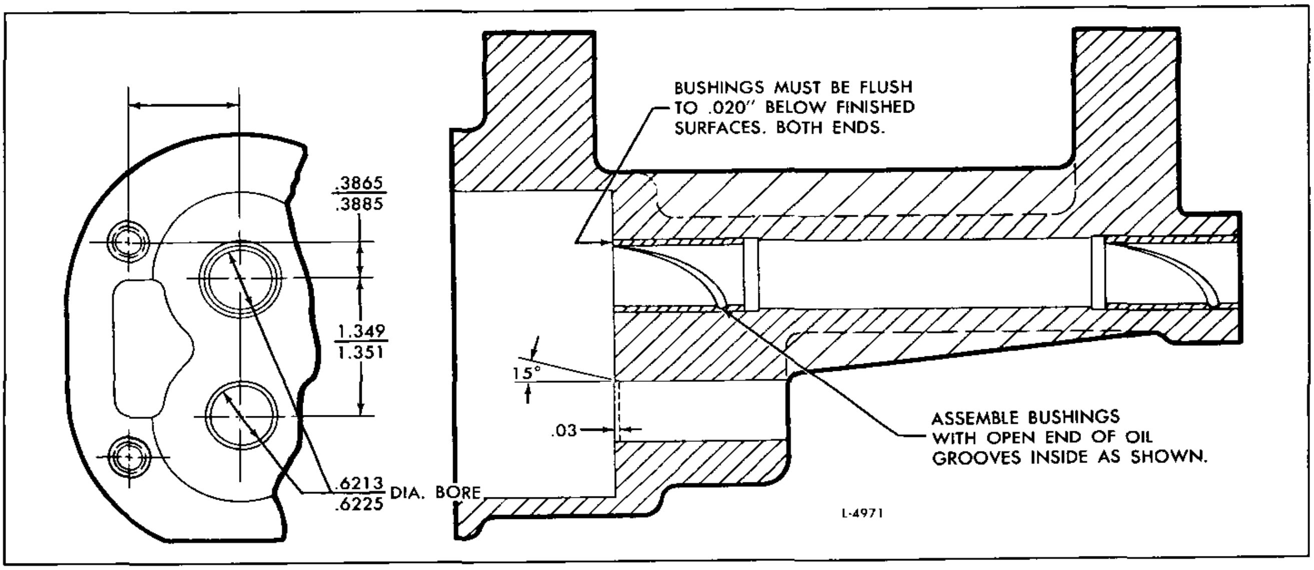


Fig. 13 – Diameter and Location of Bushings in Oil Pump Body

When installing the spacer between the oil pump body and the scavenging pump body, be sure the bleed hole is located on the discharge side of the oil pump assembly.

If the driven gear bushings are worn, replace the bushings. Then, ream the bushings to .625" ±.0005" diameter after assembly.

If the gear teeth are scored or worn, install new gears. The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious damage throughout the engine.

Inspect the external pump drive–driven gear for wear and replace it, if necessary.

Inspect the pump shafts for wear and check the keyways. Replace the shafts, if necessary.

Check to be sure the pressure relief valve moves freely in the valve housing. Replace it, if necessary.

Replace a pitted or fractured spring.

Assemble Oil Pump

Install the oil pump driven shaft and pump gear in the pump body. Install the other pump gear on the shaft in the pump cavity (Fig. 12).

Mount the cover on the two shafts, and fasten the cover on the pump with four bolts and lock washers.

Install a Woodruff key, if previously removed, in the shaft. Press the drive gear over the key on the shaft and place .006" feeler stock between the gear and the pump body. Press the gear on the shaft until the clearance between the gear and the pump body is .004" to .006" (Fig. 11).

Install Oil Pump

1. Place the pump on the No. 4 and No. 5 main bearing caps and, with shims in place, fasten the pump to the main bearing caps with four bolts and lock washers. Proper gear clearance is from .005"–.007".

   Always check the clearance between the crankshaft gear and the oil pump driving gear with the engine in the upright or running position.

2. Attach new gaskets to the oil pressure relief valve housing and fasten it to the pump and cylinder block with four bolts and lock washers.
3. Place a new gasket under the oil pump inlet pipe and fasten it to the pump body with two bolts and lock washers.
4. Fasten the oil pump screen bracket to the oil pump cover with two bolts, lock washers and nuts.

LUBRICATING OIL PRESSURE REGULATOR

IN–LINE AND 6V ENGINES

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve installed in the engine lower front cover (Figs. 1 and 2).

The oil pressure regulator consists of a hollow piston–type valve, a spring, gasket and plug. The valve is located in an oil gallery within the lower front cover and is held tight against a counterbored valve seat by the valve spring and plug. When the oil pressure exceeds a given value (Table 1), the valve is forced from its seat and the lubricating oil is bypassed into the engine oil pan.

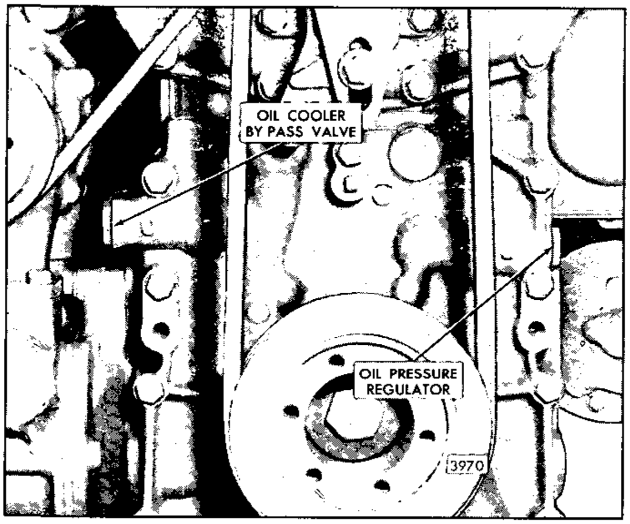


Fig. 1 – Location of Current Oil Pressure Regulator Valve (In–line Engine)

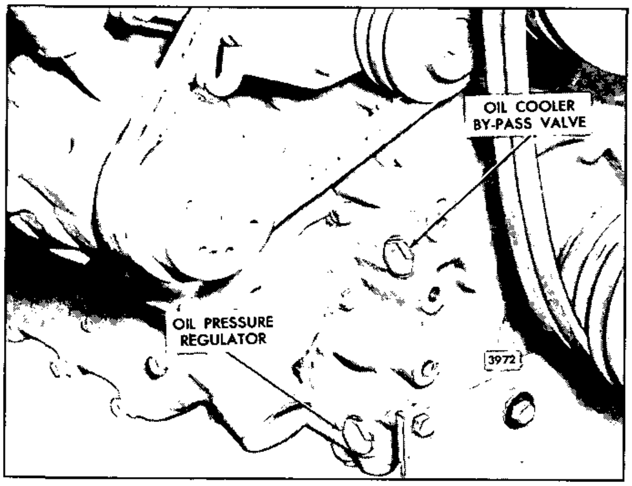


Fig. 2 – Location of Former Oil Pressure Regulator Valve (6V Engine)

Under normal conditions, the pressure regulator valve should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the plug and washer from the engine lower front cover.
2. Withdraw the spring and the valve from the cover.

Inspection

Clean all of the regulator components in fuel oil and dry them with compressed air. Then, inspect the parts for wear or damage.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

The regulator valve must move freely in the valve bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced.

Replace a fractured or pitted spring.

Engine	Plug Marks	Front Cover	Valve Opening Pressure	
			psi	kPa
In-line		Former	78	538
		Current	51	352
6V	None	Early	32	221
	R	Former	52	359
	X	Current	62	427

TABLE 1

Install Oil Pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine lower front cover, closed end first.
2. Install a new copper gasket on the plug.
3. Insert the spring in the valve.
4. While compressing the spring, start the plug in the side of the cover, then tighten the plug.

8V ENGINE

The lubricating oil pressure regulator is located in the engine front cover (Fig. 3).

A regulator assembly consists of a piston–type valve, a spring, a plug and gasket.

When the oil pressure at the valve exceeds 52 psi (359 kPa), the valve is forced from its seat and oil from the gallery passage in the front cover is bypassed to the crankcase.

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the plug and gasket from the engine front cover.
2. Withdraw the spring and valve from the cover.

Inspection

Clean the parts thoroughly in fuel oil, dry them with compressed air and inspect them.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Check to be sure the regulator valve moves freely in the engine cover valve bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced.

Replace a pitted or fractured spring.

Install Oil Pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine front cover, closed end first.
2. Install a new copper gasket on the plug.
3. While compressing the spring, start the plug in the side of the cover, then tighten the plug.

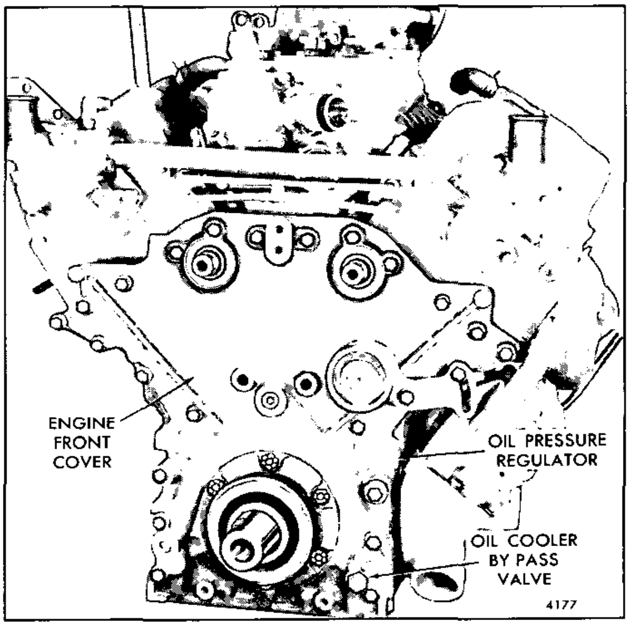


Fig. 3 – Location of Oil Pressure Regulator (8V Engine)

LUBRICATING OIL FILTERS

Series 53 engines are equipped with a full–flow type lubricating oil filter. A bypass type oil filter may be used in addition to the full–flow type filter when additional filtration is desired.

Full–Flow Oil Filter

The full–flow type lubricating oil filter is installed ahead of the oil cooler in the lubrication system (Fig. 1). On the two and three cylinder models, the oil filter shell is mounted in a downward or rearward position unless it has an adaptor to provide optional mounting positions. On the four cylinder models, the oil filter may be mounted with the filter shell up, down or toward the rear, except when on the blower side of the engine where the down and rearward positions are optional. On V–type engines, the filter is mounted at an angle down and towards the rear of the engine.

Do not reverse the flexible oil filter hoses at the filter hose adaptor on 6V and 8V marine engines equipped with a remote mounted lubricating oil filter. Refer to Fig. 2 for the proper installation of the hoses.

If the oil filter adaptor is removed from the engine for any reason, it must be reinstalled with the open half of the casting toward the top of the block. The word **TOP** is cast into the upper right corner of the adaptor. If installed in any other way, engine oil will not flow through the filter and may cause serious engine damage (Fig. 3).

The filter assembly consists of a replaceable element enclosed within a shell which is mounted on an adaptor or base. When the filter shell is in place, the element is restrained from movement by a coil spring.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter base to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud and out through another passage in the filter base and then to the oil cooler.

A valve, which opens at approximately 18–21 psi (124–145 kPa), is located in the filter base on engine mounted filters or in the hose adaptor (7/8" hoses) with a remote mounted filter and will bypass the oil directly to the oil cooler should the filter become clogged.

The spin–on lubricating oil filter (throw–away type) and mounting adaptor are now being installed on certain engines. The spin–on oil filter requires a new mounting adaptor which in some cases is part of the oil cooler cover. The oil filter assembly is serviced in a package which consists of an element and gasket (seal).

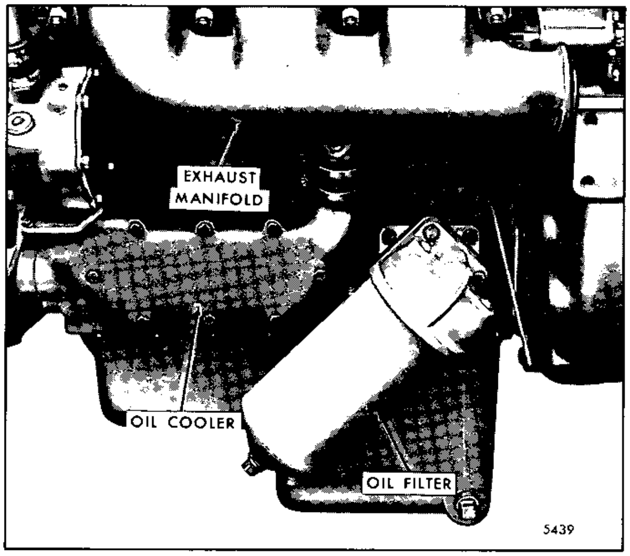


Fig. 1 – Typical Full–Flow Oil Filter Mounting (6V Engine Shown)

Bypass Oil Filter

When additional filtration is desired, an oil filter of the bypass type may also be installed on the engine (Fig. 4). However, *the size of the orifice on the discharge side of the filter must not exceed .062"* to control the oil flow rate and to provide sufficient oil pressure when the engine is running at idle speed.

When the engine is running, a portion of the lubricating oil is bled off the oil gallery and passed through the bypass filter. Eventually all of the oil passes through the filter, filtering out fine foreign particles that may be present.

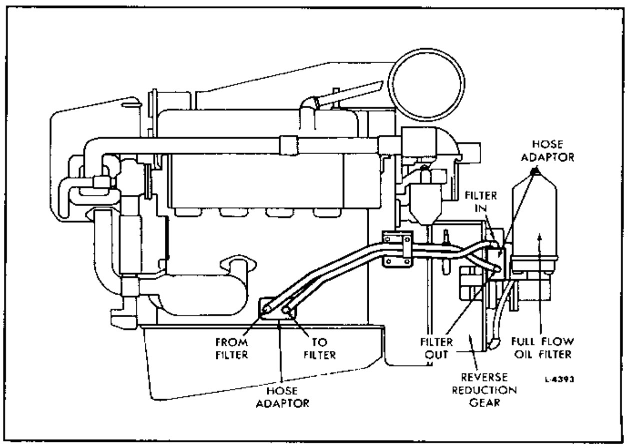


Fig. 2 – Proper Installation of Flexible Oil Filter Hoses

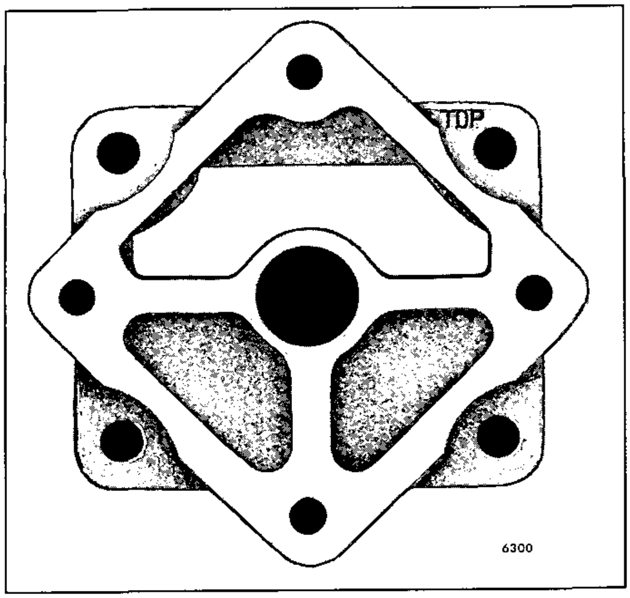


Fig. 3 – Proper Installation of Oil Filter Adaptor

The bypass filter assembly consists of a replaceable element contained in a shell mounted on a combination base and mounting bracket. When the shell is in place, the filter element is restrained from movement by a coil spring at the top. A hollow center stud serves as the outlet passage from the filter as well as securing the shell to the base.

On certain models, the filter assembly consists of a replaceable element contained in a shell and sealed in place by a cover. This type of filter assembly incorporates a mounting bracket attached to the filter shell. A hollow center stud serves as the outlet passage from the filter as well as positioning the filter element.

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter elements at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

- An optional AC service filter is available which has a synthetic (fiberglass), rather than an organic (cellulose) filtering medium. The filter is available in spin-on or canister style and is otherwise identical to the current production filter. The new filter traps particles as small as 12 microns (at 98% efficiency per AC test procedures), compared to 45 microns for the production filter. Because of its increased filtering capacity, DDC recommends using it on new, rebuilt, or newly overhauled engines being placed in service.

NOTICE: The new service filter will improve oil filtration on a properly maintained and operated engine. It will not prevent wear or malfunctions caused by poor maintanence or improper engine operation.

Replace Oil Filter Element

Replace the element in either the full-flow or bypass type oil filter assembly (Figs. 4 and 5) as follows:

1. Remove the drain plug from the filter shell or the filter adaptor or base and drain the oil. If a type S-6 filter assembly is used, oil may be removed with a sump pump after the cover and element are removed.
2. Back out the center stud or the cover nut and withdraw the shell, element and stud as an assembly. Discard the element and the shell gasket.
3. Remove the center stud and gasket. Retain the gasket unless it is damaged and oil leaks occurred.
4. Remove the nut or snap ring on the full-flow filter center stud.

   The center stud on the current full-flow oil filter has been revised by removing the snap ring groove and increasing the 5/8"-18 thread length approximately 1/2". To conform with this change, a 5/8"-18 nut replaces the snap ring formerly used to retain the filter spring and seal.
5. Remove and discard the element retainer seal (Fig. 4). Install a new seal.
6. Clean the filter shell and the adaptor or base.
7. Install the center stud gasket and slide the stud (with the spring, washer, seal and retainer installed on the full-flow filter) through the filter shell.
8. Install a new shell gasket in the filter adaptor or base.

   Before installing the filter shell gasket, be sure all of the old gasket material is removed from the filter shell and the filter adaptor or base. Also, make sure the gasket surfaces of the shell and the adaptor or base have no nicks, burrs or other damage.
9. Position the new filter element carefully over the center stud and within the shell. Then, place the shell, element and stud assembly in position on the filter

adaptor or base and tighten the stud to 50–60 lb-ft (68–81 N·m) torque.

10. Install the drain plug.

11. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough (approximately 20 minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

Replace Spin-On Filter

1. Remove the oil filter using strap wrench tool J 24783 which must be used with a 1/2" drive socket wrench and extension.

2. Discard the used oil filter.

3. Clean the filter adaptor with a clean, lint-free cloth.

4. Lightly coat the oil filter gasket (seal) with clean engine oil.

5. Start the new filter on the adaptor and *tighten by hand* until the gasket touches the mounting adaptor head. Tighten an additional two-thirds turn.

   NOTICE: Mechanical tightening will distort or crack the filter adaptor.

6. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough for oil from the various parts of the engine to drain back to the crankcase (approximately ten minutes), add sufficient oil to raise the oil level to the proper mark on the dipstick.

Remove And Install Bypass Valve

1. Remove the four bolts and washers and detach the filter adaptor or filter junction housing from the oil cooler adaptor (Fig. 5).

2. Remove the plug and gasket (Fig. 6) or the screw and retainer (Fig. 7) and withdraw the spring and bypass valve.

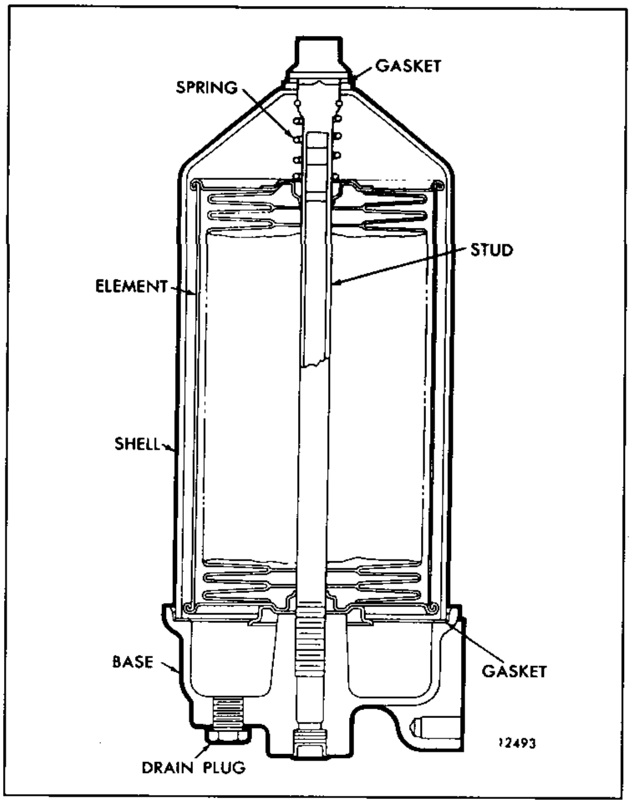


Fig. 4 – Bypass Oil Filter Details

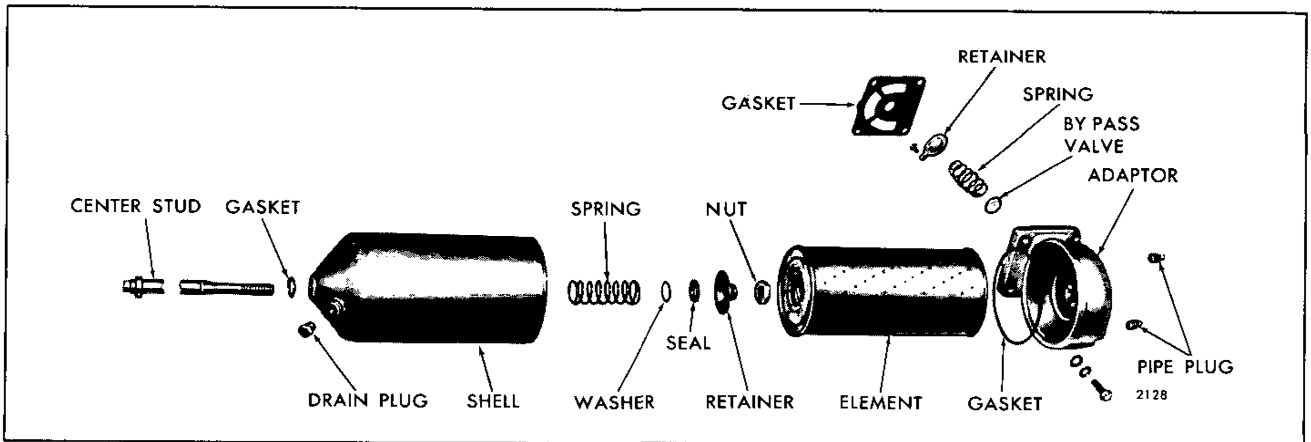


Fig. 5 – Full Flow Oil Filter Details and Relative Location of Parts

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

3. Wash all of the parts in clean fuel oil and dry them with compressed air.

4. Inspect the parts for wear. If necessary, install new parts.

5. Reassemble and install the bypass valve. Use only the current bypass valve and spring for service (Fig. 6). The current thicker valve and stiffer spring increase the bypass pressure from 13–18 psi (90–124 kPa) to 18–21 psi (124–145 kPa) to permit more efficient filtration. A thicker valve, stronger spring, heavier retainer and a longer retaining screw are currently used in the bypass valve assembly shown in Fig. 7. The filter adaptors and filter junction housings have been revised by deepening the valve cavity to accommodate the thicker valve and related parts.

6. Use a new gasket and install the filter adaptor or filter junction housing.

   NOTICE: The small protrusion on the gasket must mate with the boss on the filter adaptor regardless of the position in which the filter is assembled. If the gasket is not correctly positioned, the flow of oil will be obstructed.

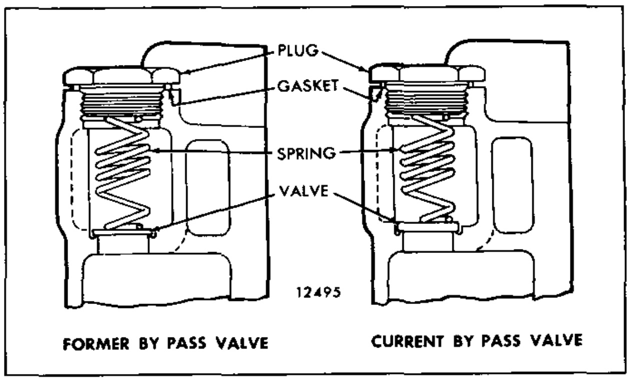


Fig. 6 – Bypass Valve Assembly Secured by Plug

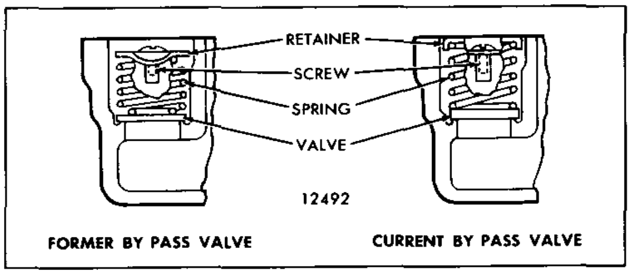


Fig. 7 – Bypass Valve Assembly Secured by Retainer and Screw

LUBRICATING OIL COOLER

Engine oil coolers are provided for all engines with the exception of certain 2–cylinder models which do not include or require an oil cooler. The oil cooler is mounted on the side of the cylinder block (Fig. 1).

To assure engine lubrication should the oil cooler become plugged, a bypass valve located near the top of the lower engine front cover bypasses oil from the oil pump discharge port directly to the oil galleries in the cylinder block. The bypass valve opens at approximately 52 psi (359 kPa) (current In–line engines), 30 psi (207 kPa) (former In–line engines) or 52 psi (359 kPa) (6V and 8V engines). The valve components are the same as and serviced in the same manner as the oil pressure regulator valve in Section 4.1.1.

The bypass valve opens at approximately 32 psi (221 kPa) on 6V marine engines prior to engine number 6D–11074 and all 6V engines prior to engine number 6D–17960.

Coolant circulated through the oil cooler completely surrounds the oil cooler core. Therefore, whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing on an In–line engine is attached to an oil cooler adaptor which, in turn, is attached to the cylinder block. The flow of oil is from the oil pump through a passage in the oil cooler adaptor to the full flow oil filter, which is also mounted on the oil cooler adaptor, and then through the oil cooler core and the cylinder block oil galleries.

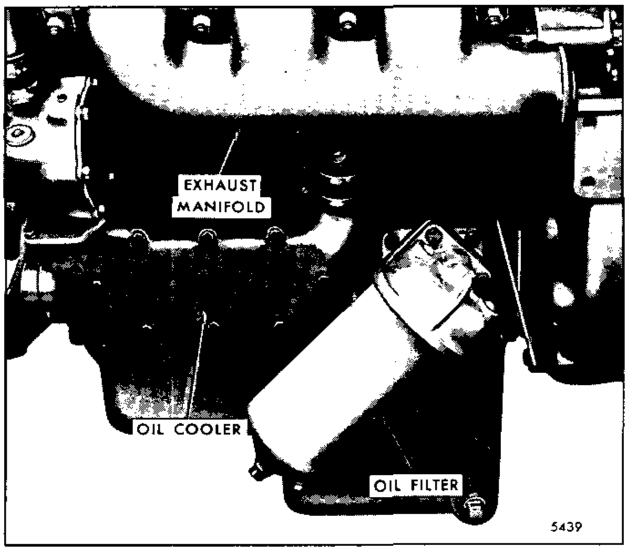


Fig. 1 – Typical Oil Cooler Mounting (6V Engine Shown)

The oil cooler housing on a V–type engine is attached directly to the cylinder block.

In order to standardize, a new aluminum oil cooler cover has replaced two cast iron covers. The new oil cooler cover has two inlet holes (to filter) and two outlet holes (from filter). One each of these holes must be plugged when the new cover is used (Fig. 2). Different attaching bolts are required because of varying cover flange thicknesses. Only the new aluminum oil cooler cover will be serviced.

Effective with engine serial number 4DB–48774 the 4–53 turbocharged engine uses a 12 plate oil cooler with a reinforced oil cooler core. When replacing an oil cooler on a 4–53 turbocharged engine built prior to the above serial number use the reinforced oil cooler assembly.

Remove Oil Cooler Core

1. Drain the cooling system by opening the drain cock at the bottom of the oil cooler housing.
2. Remove any accessories or other equipment necessary to provide access to the cooler.
3. On In–line or 6V engines, loosen and slide the clamps and hose back on the water inlet elbow on the cylinder block. On 8V engines, remove the bolt and lock washer attaching the water outlet flange and seal ring to the cylinder block.
4. Loosen and slide the clamps and hose back on the tube leading from the thermostat to the water pump.
5. Remove the bolts and lock washers which attach the water pump to the oil cooler housing.
6. Matchmark the end of the oil cooler housing, cooler core and adaptor with a punch or file so they can be reinstalled in the same position.
7. Remove the bolts and lock washers which attach the oil cooler housing to the adaptor or cylinder block and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the cooler core.
8. If the adaptor (In–line engine) is to be removed, the oil filter must first be removed. Then, remove the bolts and lock washers which attach the adaptor to the cylinder block. Withdraw the adaptor and gaskets.
9. Remove all traces of gasket material from the cylinder block and the oil cooler components.

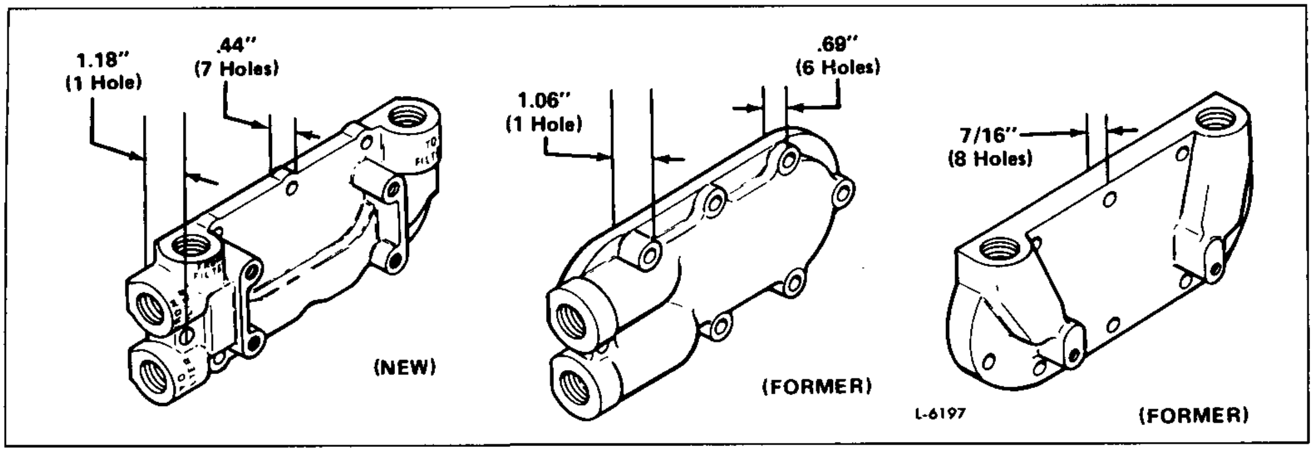


Fig. 2 – Oil Cooler Cover

Clean Oil Cooler Core

1. *Clean oil side of core* – Remove the core from the oil cooler. Circulate a solution of 1,1,1 tricholorethane through the core passages with a force pump to remove the carbon and sludge.

   CAUTION: To avoid personal injury, perform this operation in the open or in a well ventilated area. Avoid breathing the fumes or direct contact of the chemicals with your skin. Use recommended safety equipment as required.

   Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate a cleaning solution through the core and flush thoroughly with clean, hot water.

2. *Clean water side of core* – After cleaning the oil side of the core, immerse it in the following solution:

   Add one–half pound of oxalic acid to each two and one–half gallons of solution composed of one third muriatic acid and two–thirds water. The cleaning action is evidenced by bubbling and foaming.

   Watch the process carefully and, when bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

   NOTICE: Do not attempt to clean or reuse an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. Replace the oil cooler core.

Pressure Check Oil Cooler Core

After the oil cooler core has been cleaned, check for leaks as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to assure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the core (Fig. 3).

2. Attach an air hose, apply approximately 75–150 psi (517–1034 kPa) air pressure and submerge the oil cooler core and plate assembly in a container of water heated to 180°F (82°C). Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

   CAUTION: When making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

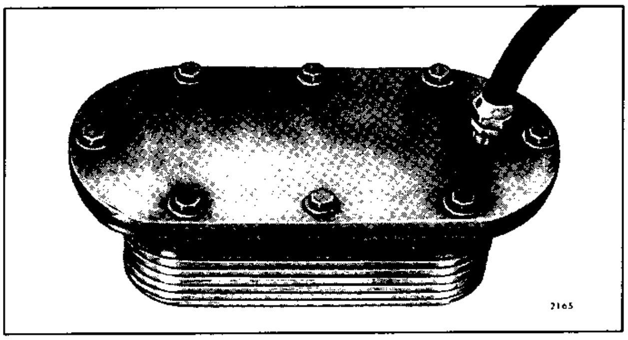


Fig. 3 – Preparing Oil Cooler Core for Pressure Test

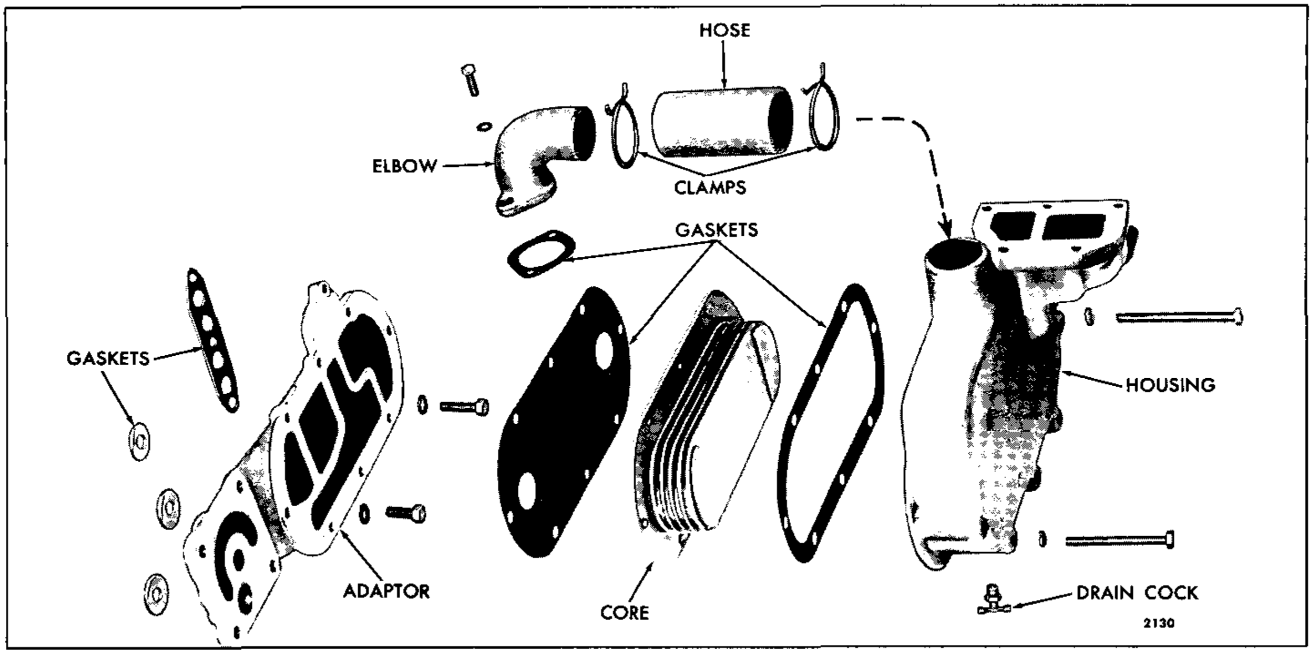


Fig. 4 – Oil Cooler Details and Relative Location of Parts (In–Line Engine)

3. After the pressure check is completed, remove the plate and air hose from the cooler core, then dry the core with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

NOTICE: Where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent serious damage (refer to Section 5).

Install Oil Cooler Core

To provide increased oil cooler capacity, an 18–plate oil cooler is being used in all 6V–53T units with engine–mounted oil coolers. DDC recommends replacing the former 16–plate core with the 18–plate core at time of engine overhaul or if the former core is damaged.

1. If the oil cooler adaptor (In–line engines) was removed from the cylinder block, remove the old gasket material from the bosses where the adaptor sets against the block. Affix new adaptor gasket and shims, then secure the adaptor to the cylinder block with five bolts and lock washers (Fig. 4). A nitrile base oil cooler to adaptor gasket is currently used on vehicle engines equipped with the AT540 transmission. The new gasket (charcoal colored) is more compatible with transmission fluid than the former gasket (beige color).

2. Clean the old gasket material from both faces of the core flange and affix new gaskets to the inner and outer faces (Figs. 4 and 5). Insert the core into the cooler housing.

NOTICE: The inlet and outlet openings in the oil cooler core are stamped *in* and *out*. It is very important that the core be installed in the correct position to prevent any possibility of foreign particles and sludge, which may not have been removed in cleaning the fins of the core, entering and circulating through the engine.

3. Align the matchmarks previously placed on the core and housing and install the oil cooler core in the oil cooler housing.

4. With the matchmarks in alignment, place the oil cooler housing and core against the oil cooler adaptor (In–line engines) or cylinder block (6V or 8V engines). On 8V engines, slide the water outlet flange and a new seal ring over the outlet. Then, secure the housing in place with bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N·m) torque. On 8V engines, secure the outlet flange in place with two bolts and lock washers.

5. Slide the hose and clamps in position between the cylinder block water inlet elbow and the oil cooler. Secure the clamps in place.

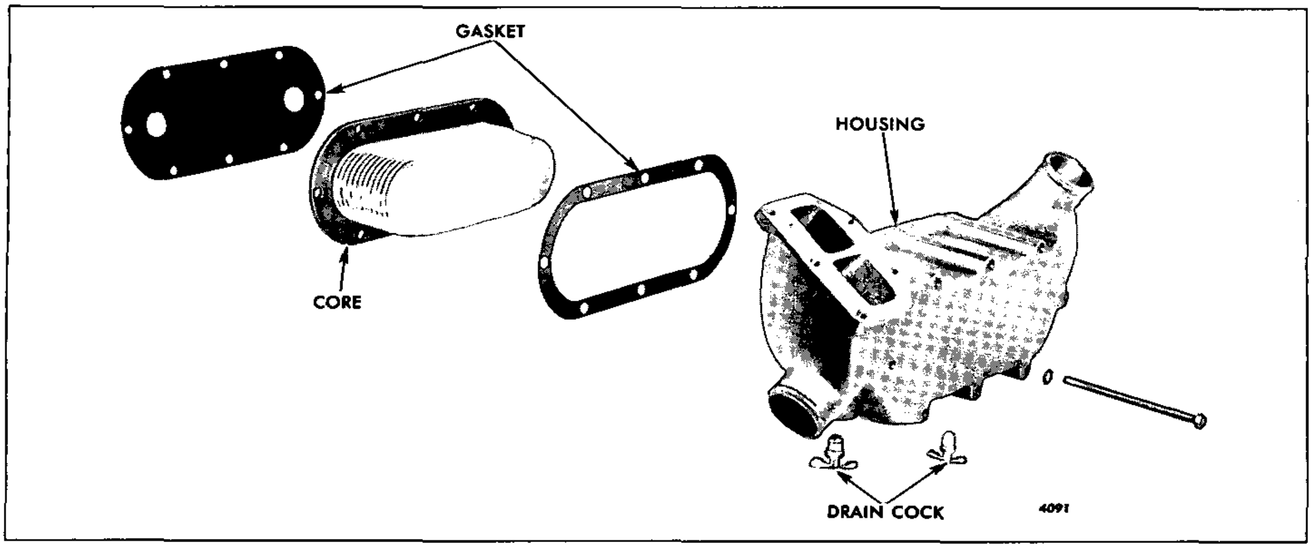


Fig. 5 – Oil Cooler Details and Relative Location of Parts (6V or 8V engine)

6. Place a new gasket between the water pump and the cooler housing and secure the pump to the cooler housing.

7. Position the hose and clamps in place between the water pump and the tube to the thermostat housing. Secure the clamps.

8. Install all of the accessories or equipment it was necessary to remove.

9. Reinstall the oil filter (In–line engine).

10. Make sure the draincock in the bottom of the cooler housing is closed. Then, fill the cooling system to the proper level.

OIL LEVEL DIPSTICK

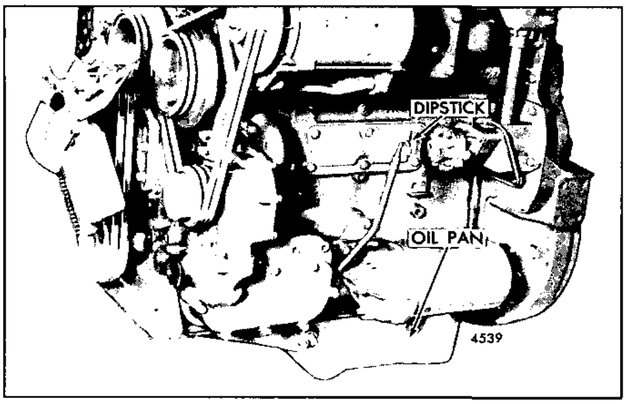


Fig. 1 – Typical Oil Dipstick Mounting

A steel ribbon type oil level dipstick is mounted in an adaptor on the side of the engine (Fig. 1) to check the amount of oil in the engine oil pan. The dipstick has markings to indicate the *Low* and *Full* oil level. Current engines include a 3/4" long rubber oil seal inside the cap of the dipstick. This prevents the escape of vapors carrying oil from the dipstick tube.

On 8V engines, effective with 8D–468, a new dipstick, adaptor and guide combination is used to raise the full mark on the dipstick approximately two quarts (1.893 litres). When replacement of any part of the combination is required on an early engine, the complete new combination is necessary.

Maintain the oil level between the *full* and *low* marks on the dipstick and never allow it to drop below the *low* mark. No advantage is gained by having the oil level above the *full* mark. Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aeration of the oil. Operation below the *low* mark will expose the pump pick–up causing aeration and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:

1. Fill the oil pan to the full mark on the dipstick.
2. Start and run the engine for approximately ten minutes.
3. *Stop the engine and wait a minimum of twenty* minutes. Then add the required amount of oil to reach the *full* mark on the dipstick.

Marine Engines

Dipsticks in marine engines are located and marked to provide the proper oil level at any angle within the recommended maximum installation angle applicable to the specific boat.

In a properly filled crankcase, the oil level must be below the crankshaft rear oil seal when the boat is at rest.

OIL PAN

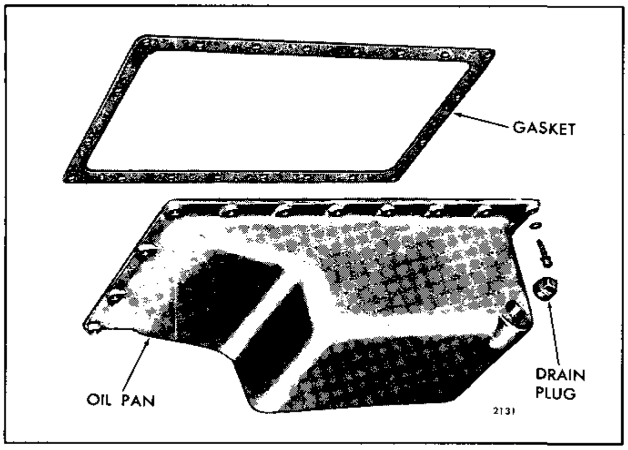


Fig. 1 – Typical Oil Pan

The oil pan (Fig. 1) may be made of steel, cast iron or cast aluminum. A shallow or deep sump type oil pan is used, depending upon the particular engine application. A one–piece oil pan gasket is used with stamped steel pans. A four–piece gasket is used with the cast oil pans.

Removing and Installing Oil Pan

On some engine applications, it may be possible to remove the oil pan without removing the engine. It is recommended that if the engine is to be removed, the oil pan be left in place until the engine is removed.

The procedure for removing the oil pan without taking the engine out and after taking the engine out of the unit will vary. However, the following will generally apply:

1. Remove the drain plug and drain the oil.

2. Detach the oil pan; take precautions to avoid damaging the oil pump inlet pipe and screen.

   NOTICE: Stamped oil pans used on some marine engines have a layer of lead or cadmium beneath the paint to protect the pans against the salt water atmosphere encountered in some marine applications. If this coating is scuffed or broken unknowingly, corrosion or electrolysis may result. Electrolysis in the form of small holes will eat through the pan at the scuffed area. Therefore, do not rest, slide or rock the engine on its oil pan when removing it. Every precaution should be taken before installation to prevent nicks and scratches on stamped marine oil pans. Also, exercise care when performing engine repairs to avoid scratching the outer surface of the oil pan.

3. Remove the oil pan gasket completely.

4. Clean all of the old gasket material from the cylinder block and the oil pan. Clean the oil pan with a suitable solvent and dry it with compressed air.

   • **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

5. Inspect a cast oil pan for porosity or cracks. Check a stamped oil pan for dents or breaks in the metal which may necessitate repair or replacement. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

6. When installing the oil pan, use a new gasket and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the bolts to 10–20 lb–ft (14–27 N·m) torque. *Do not overtighten the bolts.* Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current type gaskets. If a leak should develop at the oil pan, check if the lock washer is compressed. If not, the bolt may be tightened. However, if the lock washer is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage.

   Current oil pan bolts (stamped metal pans) are coated with a locking material. To re–activate the locking ability of the bolts, apply a drop or two of Loctite J 26558–242, or equivalent, to the threads of the bolts at reassembly.

7. On 8V engines, if the oil pan and flywheel housing include outriggers for the installation of reinforcement bolts, be sure the oil pan butts up against the flywheel housing before tightening the oil pan bolts. Install and tighten the 1/2"–13 reinforcement bolts.

8. Install and tighten the oil drain plug. Tighten the plug (with nylon washer) to 25–35 lb–ft (34–47 N·m) *torque.*

9. Fill the oil pan with new oil (refer to Sections 4.6 and 13.3) to the full mark on the dipstick. Then start and run the engine for ten minutes and check for oil leaks.

10. Stop the engine and, after approximately twenty minutes, check the oil level. Add oil if necessary.

VENTILATING SYSTEM

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the airbox past the piston rings. This air sweeps up through the engine and is drawn off through a crankcase breather.

In–line engines are equipped with a breather assembly attached to the valve rocker cover (Fig. 1) or a breather assembly mounted on the flywheel housing (Fig. 2).

On 6V engines, a breather assembly is mounted on the upper engine front cover (Fig. 3) or the rocker cover (Fig. 4).

The 8V engines have a breather tube attached to the valve rocker cover (Fig. 5) and a breather (with a filter pad) mounted on the governor. However, the marine engines did not include a filter pad until engine number 8D–2701. Early 8V engines were equipped only with a breather assembly mounted on the governor housing.

Service

It is recommended that the breather tube be inspected and cleaned, if necessary, to eliminate the possibility of clogging. This can best be done by removing the tube from the engine, washing it with a suitable solvent and drying it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

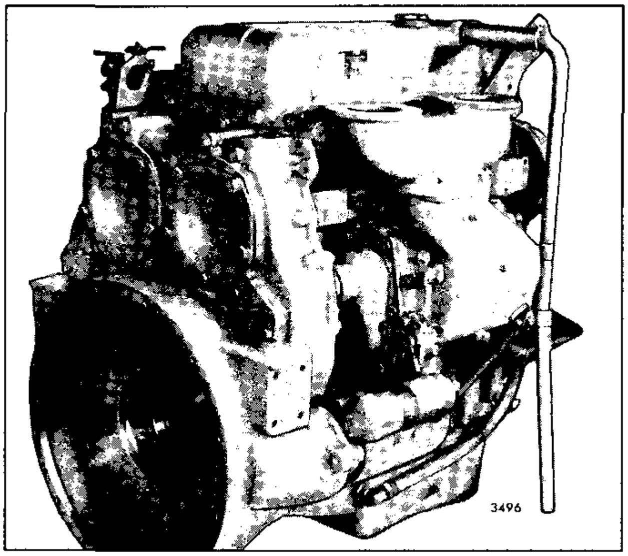


Fig. 1 – Typical Crankcase Breather Mounting (In–Line Engine)

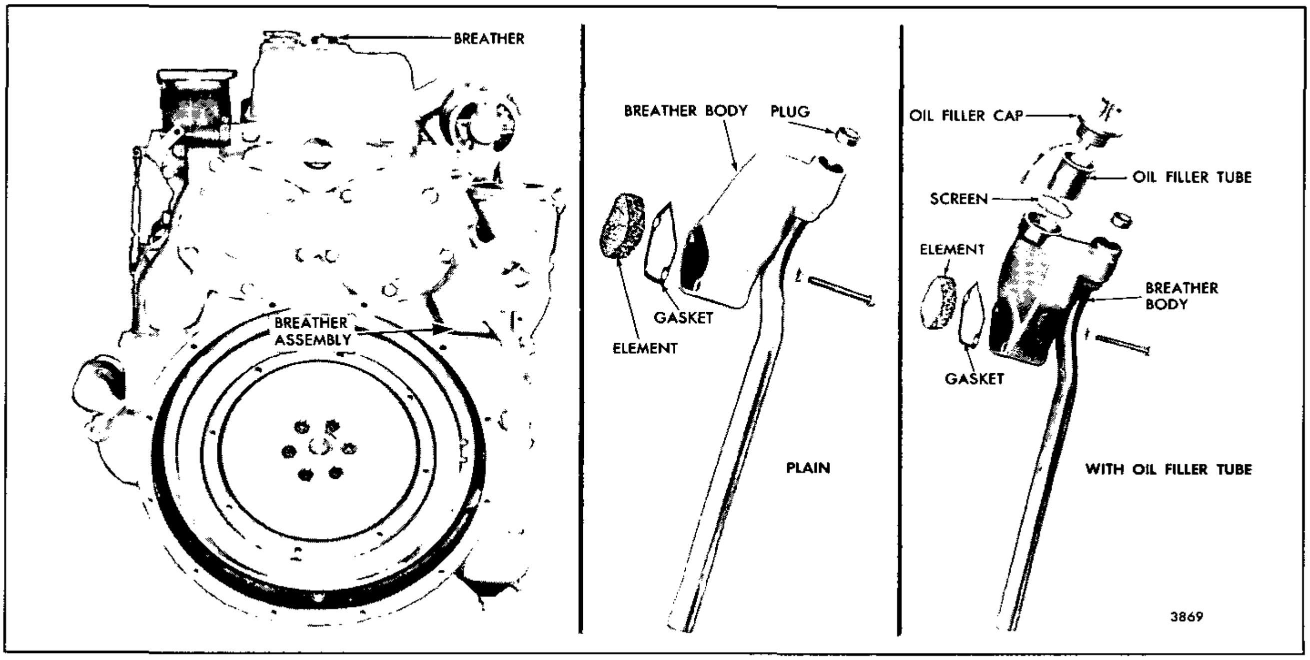
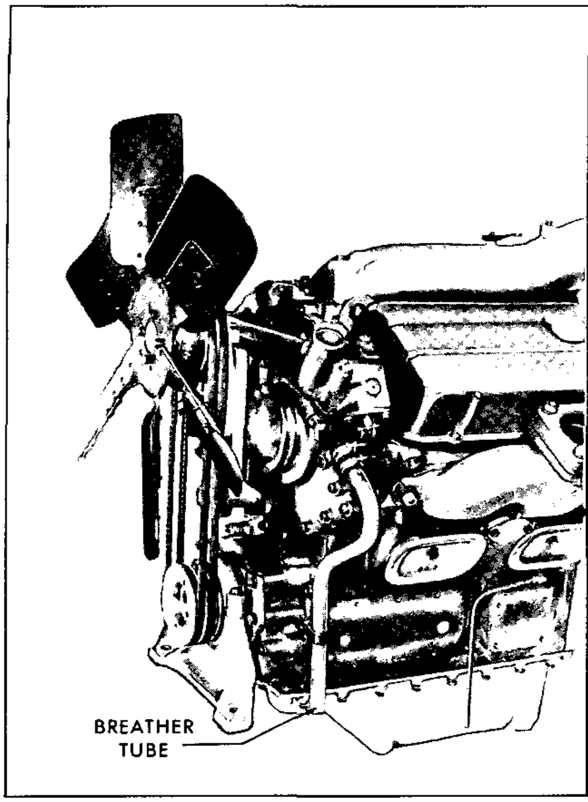


Fig. 2 – Crankcase Breather Mounting and Details (In–Line Engine)



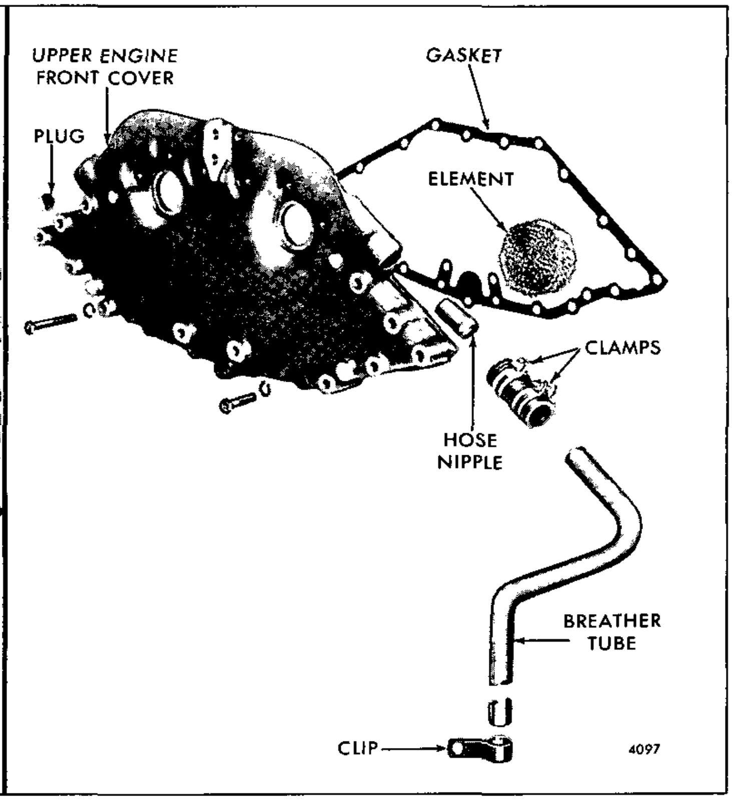


Fig. 3 – Typical Crankcase Breather Mounting and Details (6V–53 Engine)

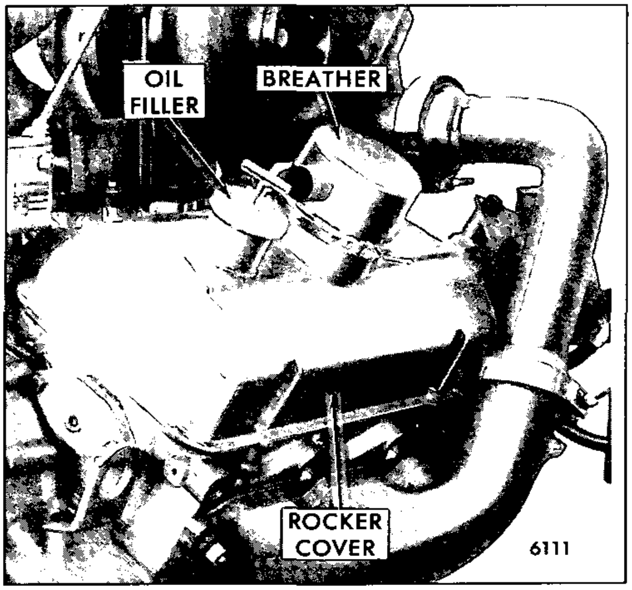


Fig. 4 – Rocker Cover Breather Mounting (6V–53 Engine)

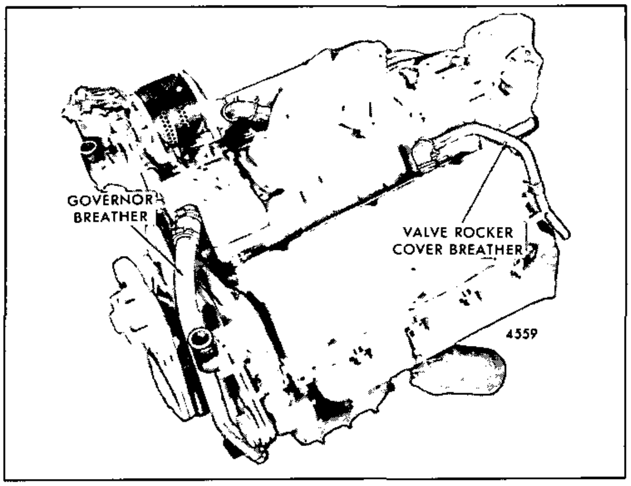


Fig. 5 – Typical Breather Mountings (8V–53 Engine)

The wire mesh pad (element) in the breather assemblies should be cleaned if excessive crankcase pressure is observed.

If it is necessary to clean the element, remove the breather housing from the flywheel housing (In–line engines), the upper front cover (6V engines), the rocker cover (6V engines) or the governor housing and/or valve rocker cover (8V engines).

Wash the element in fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Reinstall the element in the breather housing, the upper front cover or the governor housing and/or the valve rocker cover and install them by reversing the procedure for removal.

When the limiting speed governor assembly or the governor housing is replaced on an early 8V engine, it will be necessary to include the current thicker breather element.

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

REWORK INSTRUCTIONS FOR 6V-53 OIL PUMP INLET TUBE SUPPORTS

When replacing the cylinder block or main bearing caps on an early engine, it will be necessary to either replace the oil inlet tube support or elongate the bolt holes in the support (Fig. 1) and use new support attaching parts.

In the old bearing caps, the holes were tapped 5/16″-18 with 1.680″ between centers. In the new bearing caps, the holes are tapped 3/8″-16 with 2.240″ between centers.

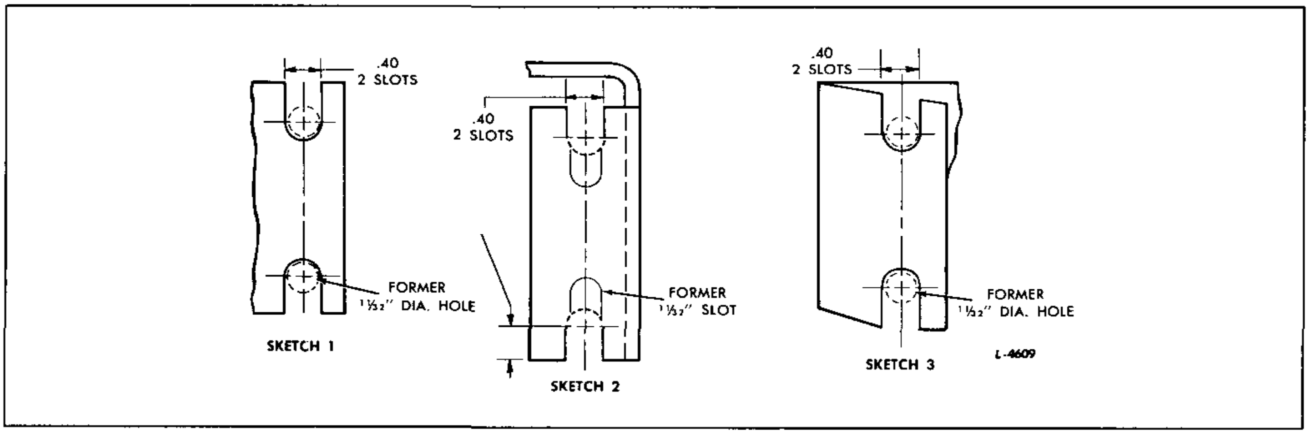


Fig. 1 - Oil Inlet Tube Supports

REWORKING 6V-53 CAST IRON OIL PAN FOR USE WITH CURRENT OIL PUMP INLET TUBE

When the seven hole upper main bearing shells (Section 1.3.4) are used in 6V marine engines prior to 6D-11074 and all 6V-engines prior to 6D-17960, a 1-3/8″ diameter lubricating oil pump inlet tube must be used rather than the former 1″ diameter inlet tube. To conform with the increased diameter of the oil pump inlet tube, the cast iron oil pan must be reworked to provide installation clearance by reducing the height of the integral cast baffle approximately .440″ (Fig. 2).

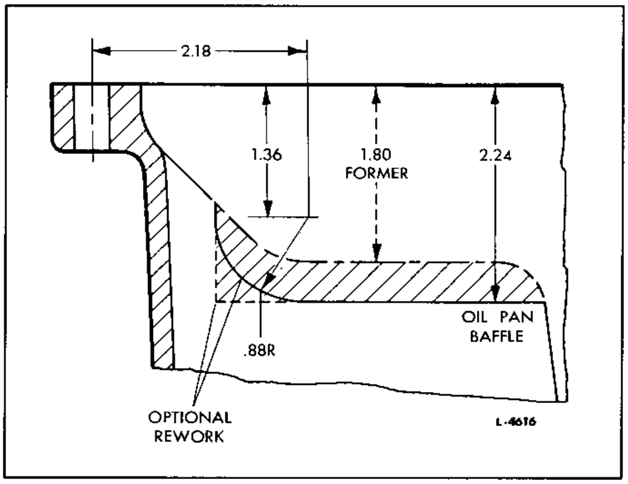


Fig. 2 - Rework Sketch for a Cast Iron Oil Pan

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	260M BOLTS TORQUE N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	280M OR BETTER TORQUE N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N·m)
Oil pan bolts	5/16–18	10–20		14–27
Oil filter center stud	5/8–18	50–60		68–81
Oil pan drain plug (Nylon washer)	18 mm	25–35		34–47

SERVICE TOOLS

TOOL NAME	TOOL NO.
Crankshaft pulley installer set	J 7773
Oil pump drive gear adaptor	J 23126
Oil pump drive gear installer	J 8968–01
Strap wrench (spin–on filter)	J 24783
Universal puller (4″ diameter range)	J 24420
Universal puller (13″ diameter range)	J 8190

SECTION 5

COOLING SYSTEM

CONTENTS

COOLING SYSTEM

To effectively dissipate the heat generated by the engine, one of three different types of cooling systems is used on a Series 53 engine: radiator and fan, heat exchanger and raw water pump, or keel cooling. A centrifugal type water pump is used to circulate the engine coolant in each system. Each system incorporates thermostats to maintain a normal engine operating temperature (refer to Section 13.2). Typical In–line and V–type engine cooling systems are shown in Figs. 1 and 2.

Radiator and Fan Cooling System

The engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block.

From the cylinder block, the coolant passes up through the cylinder head(s) and, when the engine is at normal operating temperature, through the thermostat(s) and into the upper portion of the radiator. The coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the revolving fan.

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat(s) and a bypass provides water circulation within the engine during the warm up period.

Heat Exchanger Cooling System

In the heat exchanger cooling system, the coolant is drawn by the engine water pump from the lower portion of the expansion tank through the engine oil cooler, then through the engine the same as in the radiator and fan system. Upon leaving the thermostat housing, the coolant either passes through the heat exchanger core or bypasses the heat exchanger and flows directly to the water pump, depending on the coolant temperature.

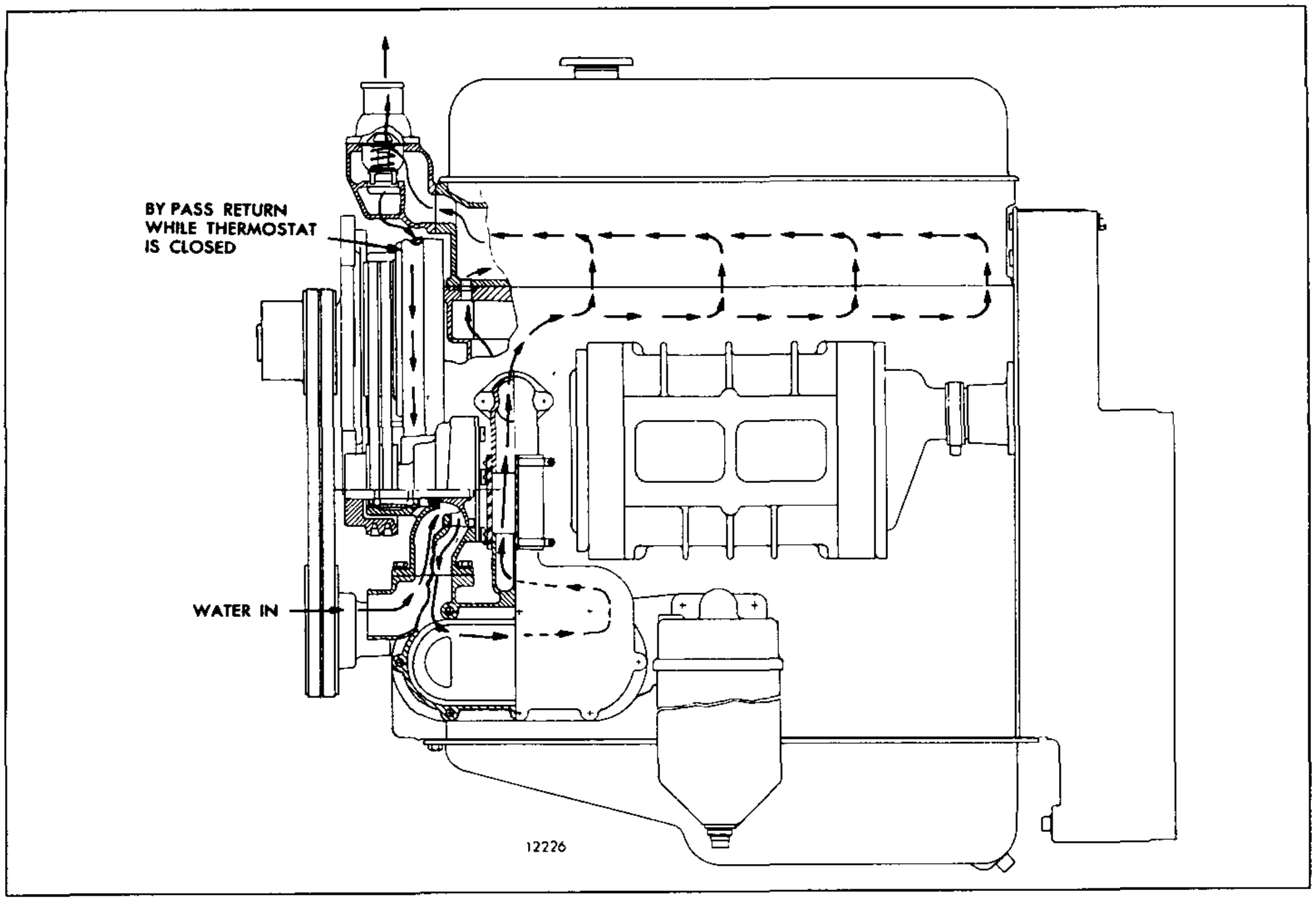


Fig. 1 – Typical Cooling System for an In-Line Engine

While passing through the core of the heat exchanger, the coolant temperature is lowered by raw water, which is drawn by the raw water (sea water) pump from an outside supply. The raw water enters the heat exchanger at one side and is discharged at the opposite side.

To protect the heat exchanger element from electrolytic action, a zinc electrode is located in both the heat exchanger inlet elbow and the raw water pump inlet elbow and extends into the raw water passage.

Keel Cooling System

The keel cooling system is similar to the heat exchanger system, except that the coolant temperature is reduced in the keel cooler. In this system the coolant is drawn by the fresh water pump from the lower portion of the expansion tank through the engine oil cooler. From the cooler the flow is the same as in the other systems. Upon leaving the thermostat housing, the coolant is bypassed directly to the lower portion of the expansion tank until the engine operating temperature, controlled by the thermostat, is reached. As the engine temperature increases, the coolant is directed to the keel cooler, where the coolant temperature is reduced before flowing back to the expansion tank.

ENGINE COOLING SYSTEM MAINTENANCE

A properly maintained and clean cooling system will reduce engine wear and increase the satisfactory engine operating time between engine overhauls. This is accomplished by the elimination of hot spots within the engine. Thus, when operating within the proper engine temperature range and when not exceeding the recommended horsepower output of the unit, all engine parts will be within their operating temperature range and at their proper operating clearances.

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from the component parts such as exhaust valves, cylinder liners and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil–to–water oil cooler. Refer to Section 13.3 for coolant recommendations.

Cooling System Capacity

The capacity of the basic engine cooling system, (cylinder block, head, water manifold, thermostat housing and oil cooler housing) is shown in Table 1.

COOLING SYTEM CAPACITY (BASIC ENGINE)		
ENGINE	CAPACITY	
	GALLONS	LITERS
2-53	1-1/2	5.7
3-53	2	7.6
4-53	2-1/4	8.5
6V-53	3-1/2	13.2
8V-53	5	18.9

TABLE 1

To obtain the total amount of coolant in the cooling system of a unit, the additional capacity of the radiator, hoses, etc. must be added to the capacity of the basic engine. The capacity of radiators and related equipment should be obtained from the equipment supplier.

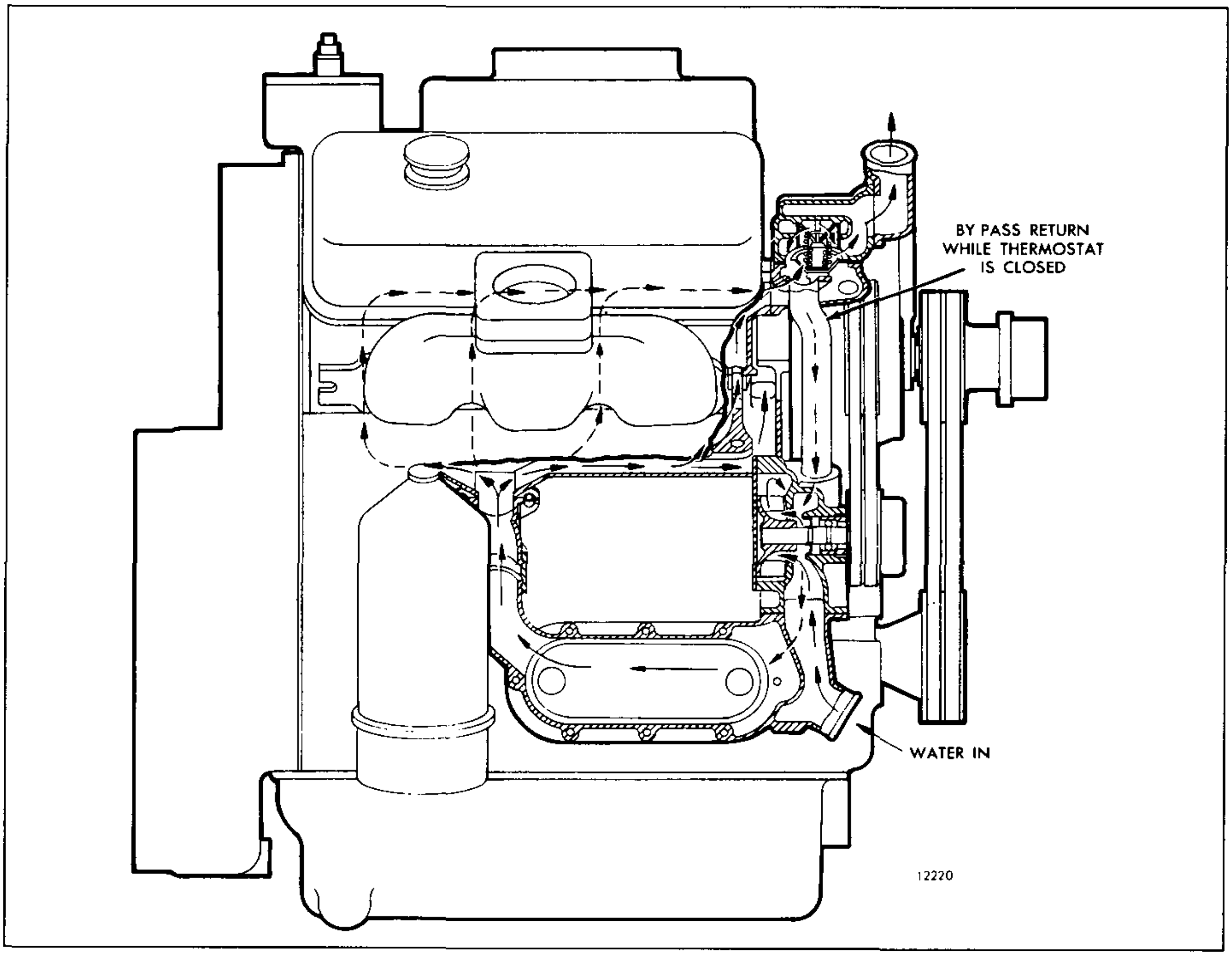


Fig. 2 – Coolant Flow Through a 6 or 8V Engine

Drain Cooling System

CAUTION: Use extreme care when removing a coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

The engine coolant is drained by opening the cylinder block and radiator (heat exchanger) drain cocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to to drain completely from the system.

Drain cocks are located as shown in Table 2.

COOLANT DRAIN VALVES		
Engine	Oil Cooler or Coolant Inlet Side of Block	Side of Block Opposite Oil Cooler or Coolant Inlet
2-53	Bottom of oil cooler or coolant inlet	*Water hole cover near front of block
3-53	Bottom of oil cooler and coolant inlet	Just forward of blower mounting pad
4-53	Bottom of oil cooler, coolant inlet, and behind blower drive or governor near rear of block	Behind blower drive or governor near rear of block
6V-53	Bottom of oil cooler, coolant inlet, and side of block near rear end	Water hole cover between hand hold covers and side of block near rear end
8V-53	Bottom of oil cooler, and side of block near rear end	Side of block near front end and below center of air box cover

*Most industrial units contain a 1/8" pipe plug at this location.

TABLE 2

In addition to the drains on the block, the oil cooler housing has a drain cock at the extreme bottom. Radiators, etc, that are not provided with a drain cock are drained through the oil cooler housing drain cock.

To ensure that all of the coolant is drained completely from a unit, all cooling system drains should be opened. Should any entrapped water in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain all units not adequately protected by antifreeze. Leave all drain cocks open until refilling cooling system.

Marine engine exhaust manifolds are cooled by the same coolant used in the engine. Whenever the engine cooling system is drained, open the exhaust manifold drain cocks.

Raw water pumps are drained by loosening the cover attaching screws and tapping the cover gently to loosen it. After the water has drained, tighten the screws.

Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with coolant (refer to Section 13.3). If the unit has a raw water pump, it should be primed, since operation without water may cause impeller failure.

Start the engine and, after the normal operating temperature has been reached allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within 2" of the top of the filler neck.

CAUTION: Use extreme care when removing a coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility of gases leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the water outlet line.

Flushing Cooling System

If a coolant filter is used and properly maintained, the cooling system need not be flushed. Otherwise, the the cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, thus cleaning the system for the next solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the unit.
2. Refill with soft clean water. If the engine is hot, fill the unit *slowly* to prevent rapid cooling and distortion of the engine castings.
3. Start the engine and operate it for 15 minutes to thoroughly circulate the water.
4. Drain the engine completely.
5. Refill with the solution required for the coming season (refer to Section 13.3).

Cooling System Cleaners

If the engine overheats and the fan and water level have been found to be satisfactory, it will be necessary to clean and flush the entire cooling system. Scale formation should be removed by using a reputable and safe descaling solvent. Immediately after using the descaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the descaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse flush before filling the system.

Reverse Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse flushed. The water pump should be removed and the radiator and engine reverse flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump.

Reverse flushing is accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, thus loosening and forcing scale deposits out.

The radiator is reverse flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.
2. Attach a hose at top of the radiator to lead water away from the engine.
3. Attach a hose to the bottom of the radiator and insert the flushing gun in the hose.
4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.
5. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

   NOTICE: Apply air gradually. Do not exert more than 30 psi (207 kPa) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse flushed as follows:

1. Remove the thermostats and the water pump.
2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
3. Attach a hose to the water outlet at the top of the engine and insert the flushing gun in the hose.
4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.
5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps. All external leaks should be corrected as soon as detected.

The fan belt must be checked and adjusted, if necessary, to provide the proper tension and the fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

Contaminated Engines

When the engine cooling or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination is a cracked oil cooler core. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating and when it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines when the cooling system is filled with an ethylene glycol base antifreeze solution. When mixed with the oil in the crankcase, this antifreeze forms a varnish which can cause the engine to seize or result in severe bearing wear.

Make certain that the cause of the internal coolant leak has been corrected before flushing the contaminated system(s).

Contaminants may be flushed from the engine systems as follows:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, this flushing procedure is recommended.

1. Prepare a mixture of Calgon, or equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.
2. Remove the engine thermostat(s) to permit the Calgon and water mixture to circulate through the engine and the radiator/heat exchanger.
3. Fill the cooling system with the Calgon solution.
4. Run the engine for five minutes.
5. Drain the cooling system.
6. Repeat Steps 1, 2, 3 and 4.
7. Fill the cooling system with clean water.
8. Let the engine run five minutes.
9. Drain the cooling system completely.
10. Install the engine thermostat(s).
11. Close all of the drains and refill the cooling system with fresh coolant (see Section 13.3).

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution, or other soluble material, the following cleaning procedure, using DPM (Dipropylene Glycol Methyl Ether), or equivalent, is recommended.

CAUTION: Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

If the engine is still in running condition, proceed as follows:

1. Drain all of the lubricating oil.
2. Remove and discard the oil filter element. Clean and dry the filter shell and replace the element.
3. Mix two parts of DPM, or equivalent, with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with this mixture.
4. Start and run the engine at a fast idle (1,000 to 1,200 rpm) for 30 minutes to one hour. Check the oil pressure frequently.
5. After the specified time, stop the engine and immediately drain the crankcase and the filter. *Sufficient time must be allowed to drain all of the fluid.*
6. Refill the crankcase with SAE 10 oil after the drain plugs are replaced and run the engine at the same fast idle for ten or fifteen minutes and again drain the oil thoroughly.
7. Remove and discard the oil filter element, clean the filter shell and install a new element.
8. Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.
9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1,000 to 1,200 rpm) for approximately 30 minutes. Then, stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.
10. If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

MAXIMUM ENGINE COOLANT TEMPERATURE

The heat–dissipating capacity of the engine cooling systems and related components must be sufficient to prevent the coolant temperature from rising above 210°F (99°C). This temperature must not be exceeded under any engine operating condition, regardless of altitude, type of coolant used or cooling system condition. Exceeding this limit can result in malfunction or serious engine damage.

• WINTERFRONTS NOT RECOMMENDED

NOTICE: The use of winterfronts (cardboard, canvas, etc.) is not recommended with any DDC engine installation. Their use can result in excessive engine coolant, oil, and charge air temperatures. This can lead to turbocharger surge, poor fuel economy, loss of power, and reduced engine life. Winterfronts may also put abnormal stress on fan and fan drive components, creating the potential for premature malfunction and/or damage.

Blocking off the radiator is done to increase the cab heat level and improve driver/passenger comfort during severe cold weather operation. This practice is normally not necessary with a properly designed and operating cooling/heater system. Preventing air leakage and reducing exposed metal surfaces in the driver/passenger compartment, plus the use of properly installed shutters, can greatly improve the comfort level.

If winterfronts are used (NOT RECOMMENDED), they should never totally close off the grill frontal area. At least a 25% area of symmetrical shape in the center of the grill should remain open at all times. At no time should the air blockage device be applied directly to the radiator core. The **exception to this is an approved shutter system.**

Qualification tests should be run by the user to determine the minimum frontal opening area required. These are some of the factors that must be considered:

- Fluctuations in ambient air temperature and load
- Ice and snow intrusion
- Wind conditions
- Vehicle speed
- Cooling system degradation
- Fuel economy loss with air–to–air charge cooling

Under no conditions should engine specification limits be exceeded. Therefore, all warning and monitoring devices should be properly located and in good working condition.

All vehicle operators *must* be given notice to adjust and/or remove winterfronts as conditions warrant to ensure proper engine operation. This is especially important on air–to–air charge cooling systems. Elevated charge air cooling temperatures cause turbocharger surging and a loss in fuel economy.

Operators *must* be advised to minimize winterfront usage. If used, the grill opening should be restricted only enough to maintain cab heat. **Do not restrict the opening so much that the elevated temperature turns on the fan.**

TEMPERATURE CONTROL COMPONENTS

These engines are designed to operate with 170°F (77°C) or 180°F (82°C) thermostats which, combined with a radiator or heat exchanger, regulate coolant temperature within a range of 170°F–187°F (77°–86°C) or 180°–197°F (82°–92°C). Many engines also use radiator shutters, clutch fans or combinations of both to help control coolant temperature. These "add on" cooling system components must operate in proper sequence to prevent coolant temperature instability and/or engine overheating.

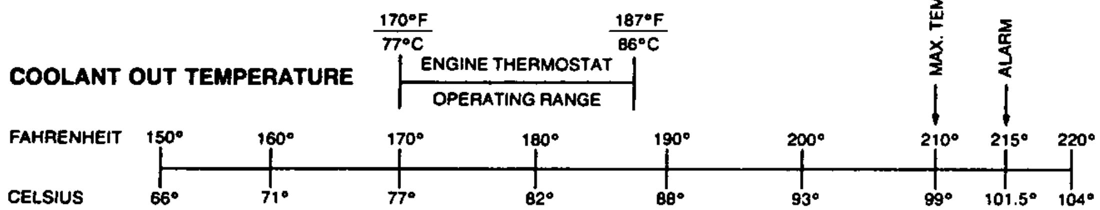
A badly adjusted operating sequence can also have a detrimental effect on the life of the "add on" components as well.

The following charts give the recommended normal temperature settings for various coolant temperature control devices. These settings should not be exceeded, since this will unnecessarily increase the engine coolant and lubricating oil temperature, possibly resulting in serious engine damage.

NOTICE: Coolant temperature instability will result from improper component operating sequence.

NOMINAL SETTINGS FOR COOLANT TEMPERATURE CONTROL DEVICES

170°F THERMOSTAT



SHUTTERS ONLY

OPTIONAL SHUTTERS		SHUTTERS	
CLOSE	OPEN	CLOSE	OPEN
160°F / 71°C	165°F / 74°C	178° - 183°F / 81° - 84°C	185° - 190°F / 85° - 88°C

CLUTCH FAN ONLY

MODULATING FAN		ON/OFF FAN	
START ON	FULL ON	OFF	ON
180°F / 82°C	192°F / 89°C	178° - 183°F / 81° - 84°C	185° - 190°F / 85° - 88°C

CLUTCH FAN AND SHUTTER COMBINATION

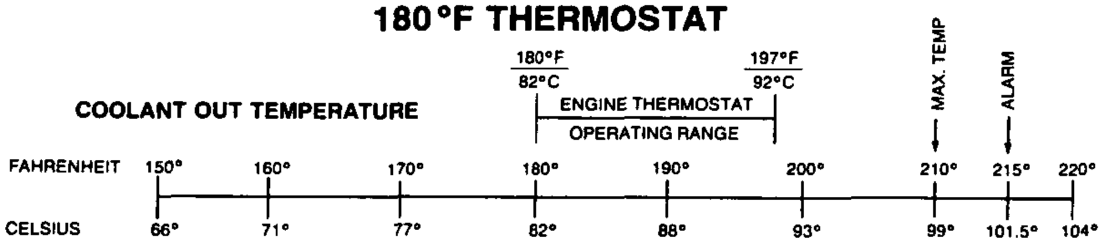
SHUTTERS		MODULATING FAN		ON/OFF FAN	
CLOSE	OPEN	START ON	FULL ON	OFF	ON
160°F / 71°C	165°F / 74°C	180°F / 82°C	192°F / 89°C	178° - 183°F / 81° - 84°C	185° - 190°F / 85° - 88°C

SHUTTER AND ON/OFF FAN CONTROL COMBINATION

SHUTTER CLOSED	FAN OFF	SHUTTER OPEN	FAN ON
178°F / 81°C	183°F / 84°C	185°F / 85°C	190°F / 88°C

CHART 1 – 170° Thermostat

NOMINAL SETTINGS FOR COOLANT TEMPERATURE CONTROL DEVICES



SHUTTERS ONLY

OPTIONAL SHUTTERS		SHUTTERS	
CLOSE	OPEN	CLOSE	OPEN
170°F / 77°C	175°F / 79.5°C	188° - 193°F / 87° - 89.5°C	195° - 200°F / 90.5° - 93°C

CLUTCH FAN ONLY

MODULATING FAN		ON/OFF FAN	
START ON	FULL ON	OFF	ON
190°F / 88°C	202°F / 94.5°C	188° - 193°F / 87° - 89.5°C	195° - 200°F / 90.5° - 93°C

CLUTCH FAN AND SHUTTER COMBINATION

SHUTTERS		MODULATING FAN		ON/OFF FAN	
CLOSE	OPEN	START ON	FULL ON	OFF	ON
170°F / 77°C	175°F / 79.5°C	190°F / 88°C	202°F / 94.5°C	188° - 193°F / 87° - 89.5°C	195° - 200°F / 90.5° - 93°C

SHUTTER AND ON/OFF FAN CONTROL COMBINATION

SHUTTER CLOSED	FAN OFF	SHUTTER OPEN	FAN ON
188°F / 87°C	193°F / 89.5°C	195°F / 90.5°C	200°F / 93°C

CHART 2 – 180° Thermostat

WATER PUMP

A centrifugal–type water pump (Figs. 1 and 2 or 3 and 4) is mounted on top of the engine oil cooler housing (Fig. 5). It circulates the coolant through the oil cooler, cylinder block, cylinder head(s) and radiator.

The pump is belt driven by either the camshaft or balance shaft (In-line engines) or by one of the camshafts (V–type engine).

An impeller is pressed onto one end of the water pump shaft, and a drive pulley is pressed onto the opposite end. The pump shaft is supported on a sealed double-row combination radial and thrust ball bearing. Coolant is prevented from creeping along the shaft toward the bearing by a seal. The shaft and bearing constitute an assembly, and are serviced as such, since the shaft serves as the inner race of the ball bearing. The sealed water pump shaft ball bearing is filled with lubricant when assembled. No further lubrication is required.

Effective with engine serial numbers 2D–27598, 3D–64888, 4D–66635, 6D–66897 and 8D–3815, the water pump assemblies include an impeller and ceramic insert combination (Figs. 4 and 6).

A new seal has been released for the fresh water pumps, effective with engine serial numbers 3D–189023, 4D–202708 and 6D–223092. The new seal has a high grade carbon face, a stainless steel case and a shroud. The former seal had a phenolic face, brass case and no shroud. Because of its design, the new seal provides improved resistance to leakage even after high engine hours or mileage. The former seal and the new seal are completely interchangeable and only the new seal will be available to service fresh water pumps.

Remove Water Pump

1. Remove the radiator cap, open the block and radiator drain cocks, and drain the cooling system.
2. Loosen and remove the water pump belts. An idler pulley is used on some engines to adjust the water pump drive belt tension.
3. Loosen the hose clamps and slide the hose up on the water bypass tube.
4. Remove the five bolts securing the water pump to the oil cooler housing and take off the pump.

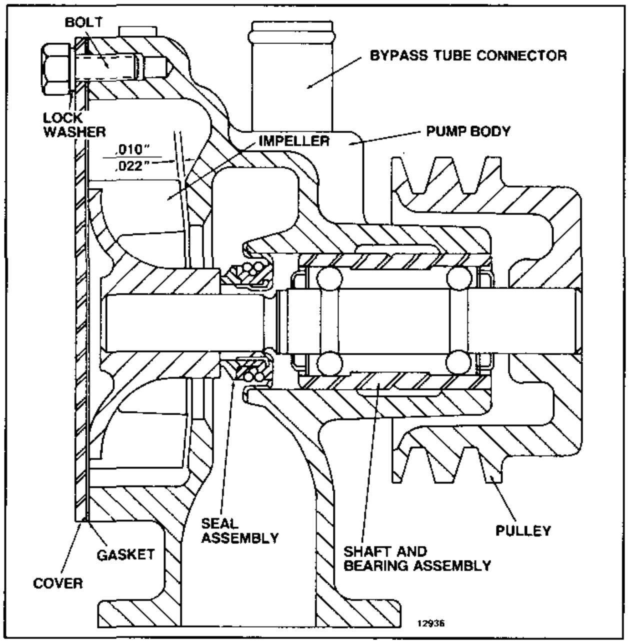


Fig. 1 – Former Water Pump Assembly

Disassemble Pump

1. Note the position of the pulley on the shaft so that the pulley can be reinstalled in the same position when the pump is reassembled. Remove the water pump pulley (Fig. 7).
2. Remove the pump cover and discard the gasket.
3. Press the shaft and bearing assembly, seal and impeller out of the pump body as an assembly, by applying pressure on the bearing outer race with remover J 1930.

   NOTICE: The bearing will be damaged if the pump is disassembled by pressing on the end of the pump shaft.

4. Use plates J 8329 and holder J 358–1 to press the shaft out of the impeller (Fig. 8).
5. Remove and discard the seal assembly from the pump shaft.

Inspection

Wash all of the pump parts, except the bearing and shaft assembly, in clean fuel oil and dry them with compressed air.

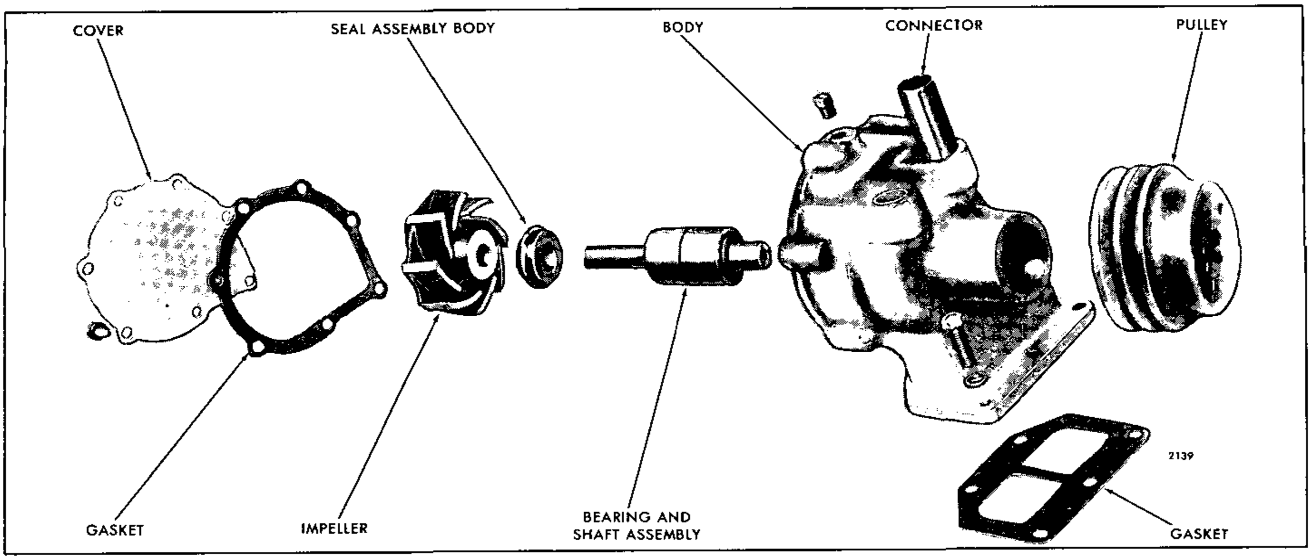


Fig. 2 – Water Pump Details and Relative Location of Parts

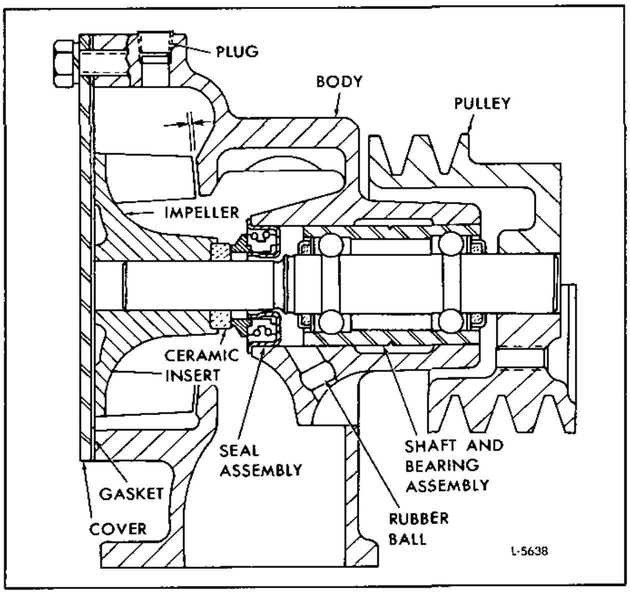


Fig. 3 – Current Water Pump Assembly

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

A permanently sealed and lubricated bearing is used in the bearing and shaft assembly and should not be washed. Wipe the bearing and shaft assembly with a clean lintless cloth. Discard the bearing if it has a general feeling of roughness, is tight, or has indications of damage.

A 7/16″ rubber ball is installed in the weep hole of certain water pumps (Fig. 3). Examine the ball and replace if damaged or deteriorated.

Inspect the water pump impeller for wear (erosion) and reuse or replace, as required. If the impeller is reused, the ceramic impeller insert *must* be replaced.

- Never attempt to reuse the ceramic insert, regardless of its apparent condition. A worn ceramic insert may leak. Always replace the insert or impeller assembly (with insert) at time of water pump overhaul. Bond a new ceramic impeller insert to the impeller, as follows:

1. Bake the insert and impeller assembly at 500°F (260°C) for 90 minutes. The insert can be removed easily while the adhesive is hot. After removing the insert, clean the insert area of the impeller with sandpaper, wire brush or a buffing wheel to remove the old adhesive, oxide, scale, etc.
2. Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller insert area and the grooved side of a new ceramic insert. Then, wipe the parts with a clean, dry cloth.
3. Place two (2) adhesive washers in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler (Fig. 6).

NOTICE: Adhesive washers are tan in color but have a white paper backing which must be removed and discarded before the washers can be used. Failure to remove the paper backing will result in a weak or ineffective bond between the insert and impeller.

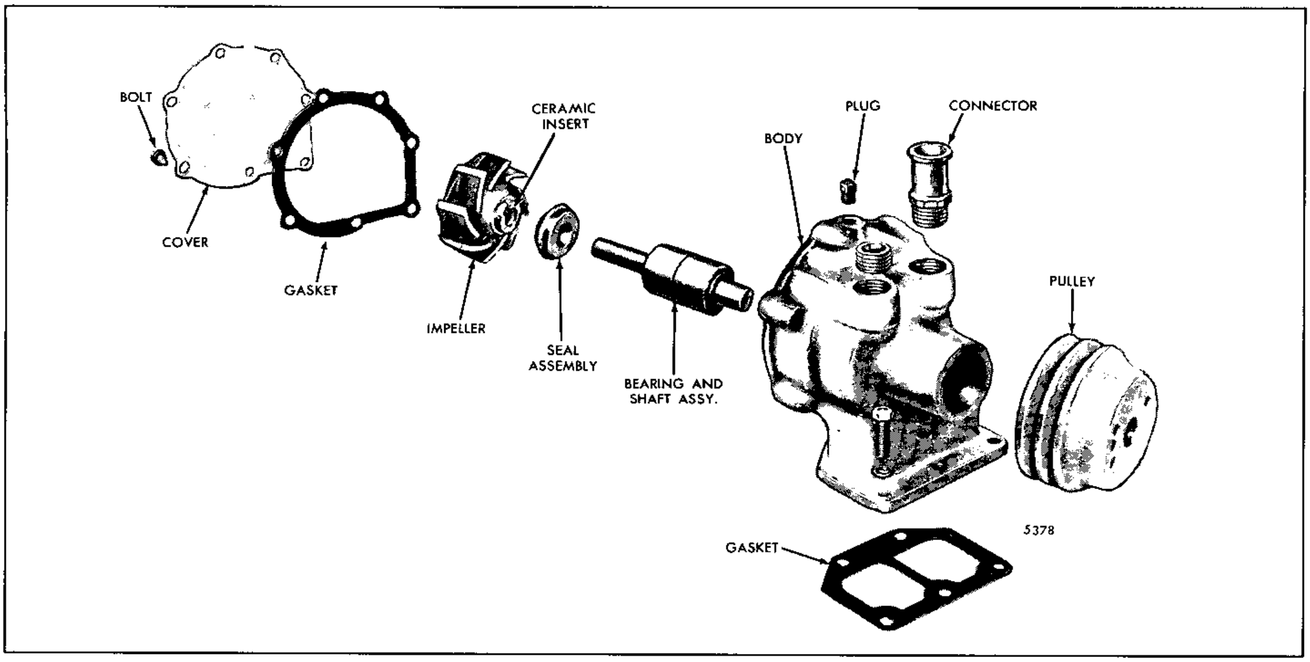


Fig. 4 – Details of Current Water Pump Assembly with Ceramic Seal

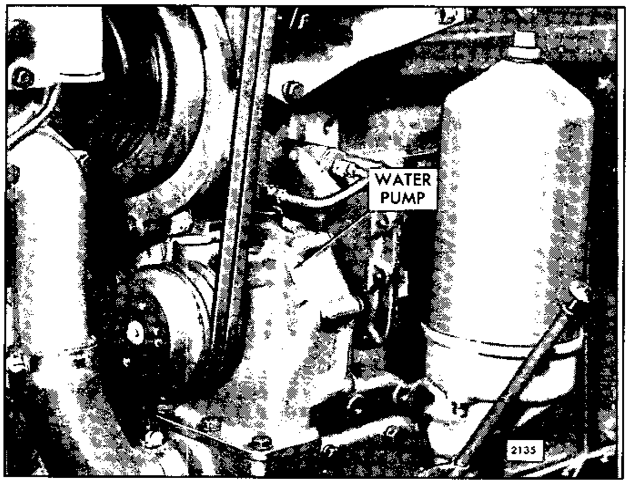


Fig. 5 – Typical Water Pump Mounting

4. Clamp the ceramic insert and impeller together with a 3/8" bolt and nut and two *smooth* .125" thick washers. The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for this inspection. Tighten the bolt to 10 lb–ft (14 N·m) torque. Do not mar the polished surface of the ceramic insert.

5. Place the impeller assembly in a level position, with the ceramic insert up, in an oven preheated to 350°F (177°C) for one hour to cure the adhesive.

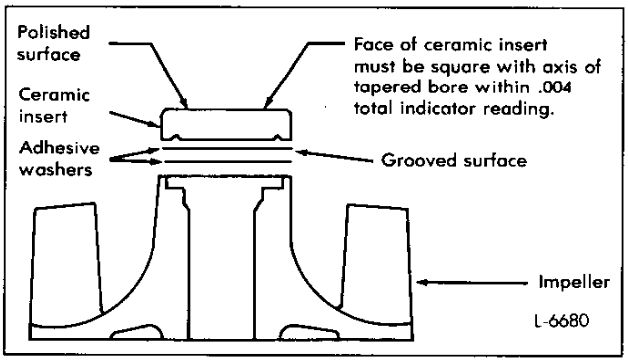


Fig. 6 – Insert, Adhesive Washer, Impeller Stackup

6. Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen or remove the clamping bolt and washers until the assembly cools.

Assemble Pump

1. Use installer J 1930 to apply pressure to the outer race of the bearing (Fig. 9) and press the shaft and bearing assembly into the pump body until the outer race of the bearing is flush with the outer face of the body.

   NOTICE: The bearing will be damaged if the bearing and shaft assembly is installed by applying pressure on the end of the shaft.

2. To reduce possible coolant leakage, apply a light coat of non–hardening sealant on the outside of a new seal.

Then, with the face of the pump body and the bearing outer race supported, install the seal by applying pressure on the seal outer flange only, until the flange contacts the pump body (Fig. 1 or 3). Wipe the face of the seal with a chamois to remove all dirt and metal particles.

3. Support the pulley end of the shaft on the bed of an arbor press and press the impeller on the shaft until the impeller is flush with the large end of the body.

4. Place the pulley on the bed of an arbor press. Place a suitable rod between the ram of the press and the impeller end of the shaft, then press the shaft into the pulley until the pulley is in its original position on the shaft.

5. Install the cover and a new gasket on the pump body. Tighten the cover bolts to 6–7 lb–ft (8–9.5 N·m) torque.

6. Run the pump dry at 1200 rpm for a minimum of 30 seconds, or as required, to assure satisfactory seating of the seal.

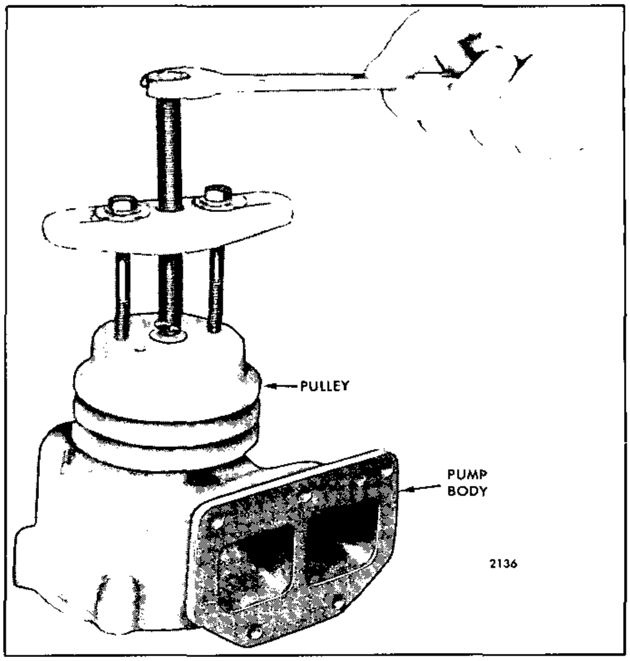


Fig. 7 – Removing Pulley Using Puller J 24420–A

Install Water Pump

1. Affix a new gasket to the flange of the water pump body.

2. Secure the water pump to the oil cooler housing with the five bolts and lock washers.

3. Install the hose between the water pump and water bypass tube and tighten the hose clamps.

4. Install and tighten the belts. An idler pulley is used on some engines to adjust the water pump drive belt tension.

5. Close all of the drain cocks and refill the cooling system.

6. Start the engine and check for leaks.

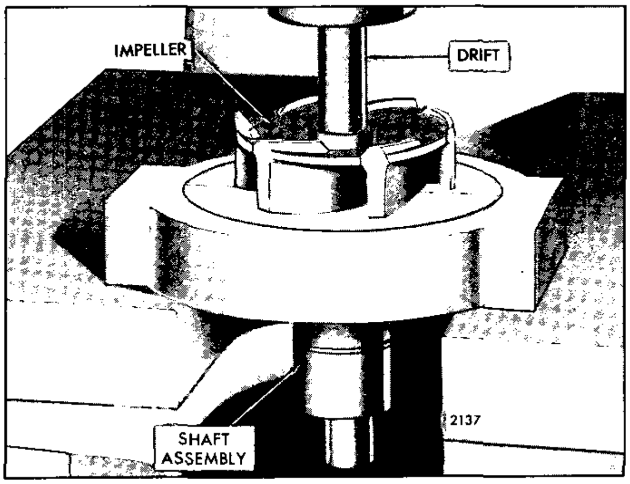


Fig. 8 – Removing Shaft from Impeller with Tools J 8329 and J 358–1

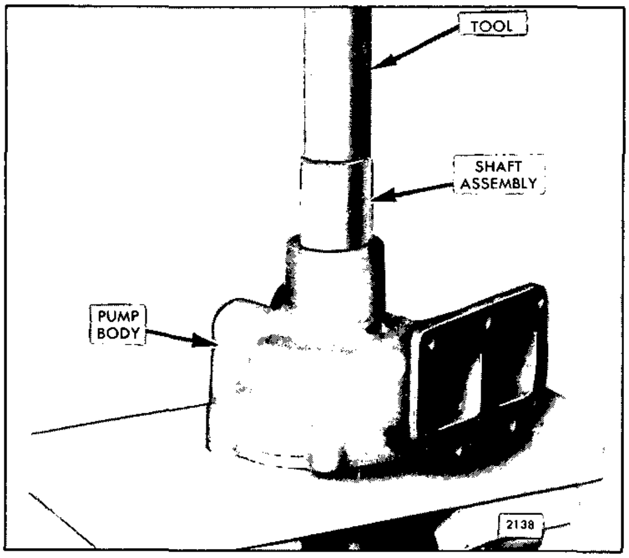


Fig. 9 – Pressing Shaft Assembly into Water Pump Using Tool J 1930

WATER PUMP IDLER PULLEY ASSEMBLY

The water pump idler pulley assembly is mounted on the upper engine front cover (Fig. 1).

Remove Idler Pulley Assembly

Remove the two attaching bolts and lift the pulley assembly away from the front cover and drive belts.

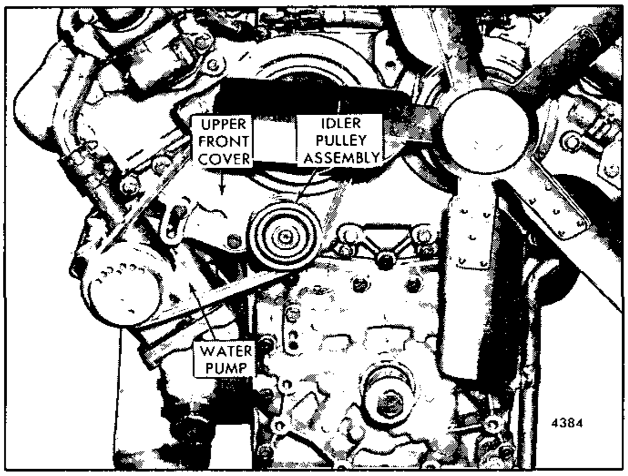


Fig. 1 – Typical Water Pump Idler Pulley Mounting

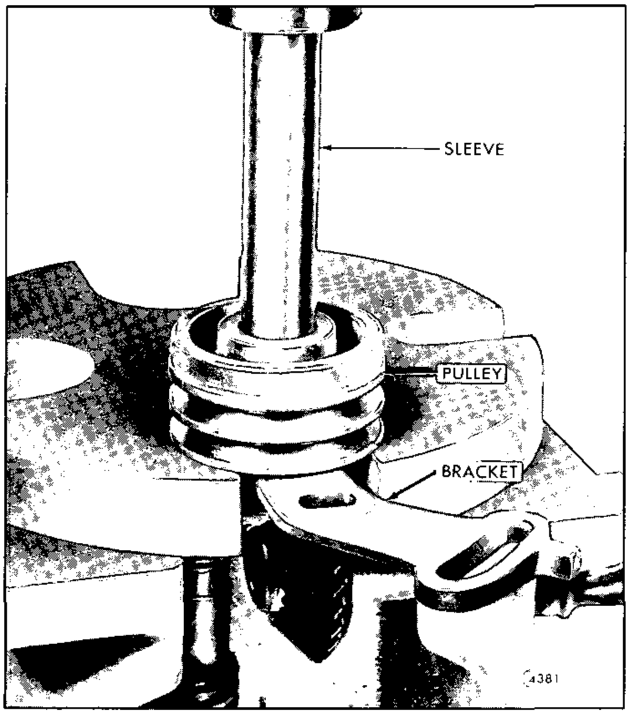


Fig. 2 – Removing Shaft and Bearing Assembly and Bracket from Idler Pulley

Disassemble Idler Pulley Assembly

1. Support the pulley, then press the shaft and bearing assembly and bracket from the pulley by applying pressure to the outer race of the bearing (Fig. 2).
2. Support the bracket and press the shaft and bearing assembly from the idler pulley bracket by applying pressure on the shaft only.

Inspection

Wash the idler pulley bracket and pulley in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

The idler pulley shaft and bearing assembly must not be washed in fuel oil. If the bearing is immersed in cleaning fluid, dirt may be washed in. The fuel oil and dirt may not be entirely removed from the bearing.

Examine the bracket and pulley for excessive wear or cracks.

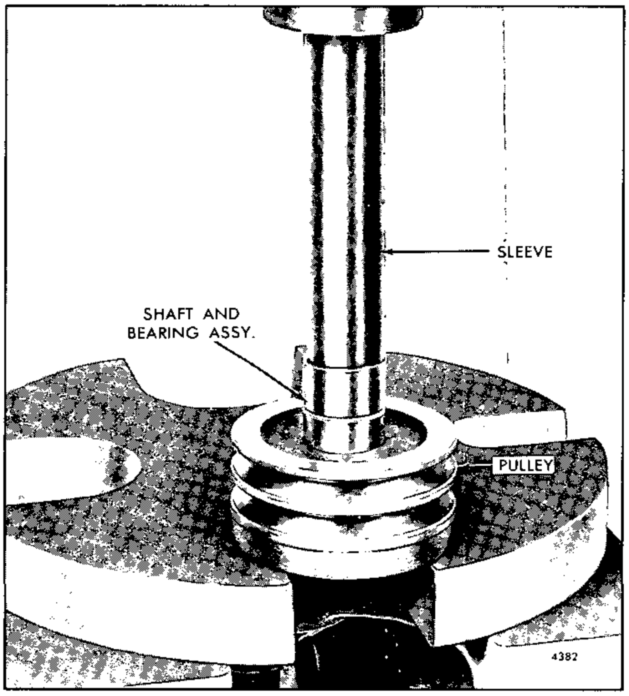


Fig. 3 – Installing Shaft and Bearing Assembly in Idler Pulley

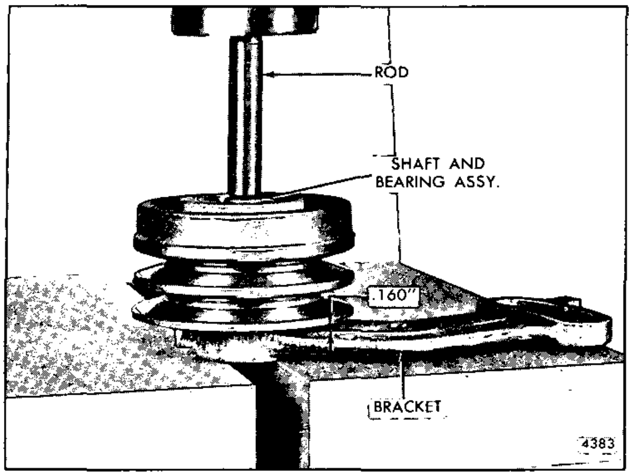


Fig. 4 – Installing Shaft and Bearing Assembly and Pulley in Bracket

Revolve the shaft slowly in the bearing by hand. If rough or tight spots are detected, the bearing and shaft assembly must be replaced.

On early engines, if the bracket or bearing assembly requires replacement, the complete idler pulley assembly must be replaced. The bearing bore diameter on the current bracket is .6237"–.6247". On the former bracket, the bearing bore diameter is .6242"–.6252".

Assemble Idler Pulley Assembly

1. Apply a minimum of 1600 lbs pressure only on the outer race of the bearing as shown in Fig. 3 and press the bearing and shaft assembly into the idler pulley until the outer race of the bearing is flush with the inside surface of the pulley.

2. With a short rod, apply pressure on the shaft only and press the shaft and bearing assembly with the pulley into the idler pulley bracket (Fig. 4). The distance between the outer edge of the pulley and the bracket must be .160".

Install Idler Pulley Assembly

1. Attach the idler pulley assembly to the front cover with two bolts and lock washers.

2. Install the water pump drive belts.

3. Adjust the idler pulley assembly so that the drive belts have the proper tension and tighten the bolts.

THERMOSTAT

The temperature of the engine coolant is automatically controlled by a blocking type thermostat located in a housing attached to the water outlet end of the cylinder head. A single thermostat is used in the in–line engines; the V–type engines use two thermostats, one at each cylinder head.

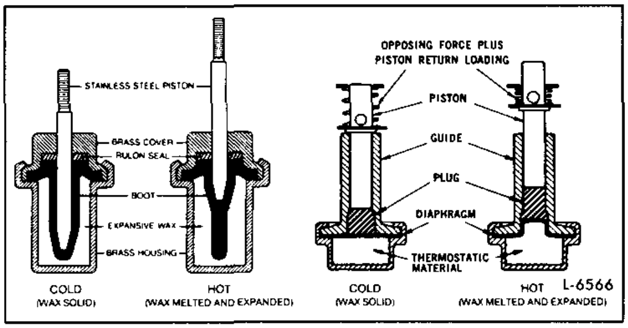


Fig. 1 – Thermostat Heat Motors

• Construction and Operation

A thermostat is a type of automatic valve which controls the flow of coolant through a radiator or other heat exchanger. The thermostat senses changes in engine coolant temperature and regulates coolant flow to maintain efficient engine operating temperature.

Thermostats used in Detroit Diesel engines consist of a brass cup filled with a heat–expansive wax–like material. The wax compound is retained within the cup by an elastometric seal. The valve of the thermostat is attached to a piston which is held on the elastomer by a spring.

Two thermostat heat motor (power element) designs are shown (Fig. 1). The basic principle (expansive wax) remains the same for all thermostats. The valve is in the closed position when the thermostat is cold (wax solid). When the wax–filled brass cup is heated by engine coolant, the wax–like material expands. As the coolant temperature in the engine reaches the calibrated "start to open" thermostat setting, the force of the expanding wax on the piston exceeds the closing force of the spring and the valve begins to open. As the coolant temperature continues to increase, the wax–like material continues to expand and the valve opens further until it reaches its maximum design travel.

As the temperature of the engine coolant drops, cooling of the wax causes it to contract. This reduces the pressure on the piston and allows the spring to draw the valve back toward its seat (closed thermostat).

Requirements

In order to perform effectively, a thermostat must meet the following requirements:

1. Start to open at a specified temperature.
2. Be fully open at a specified number of degrees above the "start to open" temperature.
3. Permit the passage of a specified amount of coolant under a specified pressure when fully open.
4. Depending on cooling system requirements, allow little or no coolant to flow to the radiator core when in the closed position.

Types

Two basic types of thermostats are used in Series 53 engines: full–blocking and non–blocking.

The full–blocking type thermostat simultaneously controls the flow of coolant to the radiator and the bypass circuit. During the engine warm–up, all engine coolant flows through the bypass circuit. As the thermostat opens, increasing amounts of coolant flow to the radiator, and the bypass flow is correspondingly reduced. At approximately 17°–20°F (9.4°–11.1°C) above the opening temperature of the thermostat, the bypass opening is fully blocked and the total flow of coolant is directed in the radiator.

The non–blocking (choke or poppet) type thermostat controls the flow of coolant only to the radiator, while the continuously open bypass sends coolant directly back to the fresh water pump and engine block. Coolant flow to the radiator discharges through the thermostat valve when coolant temperature is above the opening temperature of the thermostat (see illustration). This type is full open at 17°–20°F (9.4°–11.1°C) above the opening temperature of the thermostat.

Vented or Non–Vented

Thermostats may be vented or non–vented. Venting is accomplished with a small hole in the valve or a notch in the valve at its seat. Non–vented thermostats should be installed only in rapid warm–up type cooling systems. Vented thermostats are used primarily in conventional cooling systems.

The Rapid Warm–up Cooling System

The amount of coolant leaking to the radiator when the thermostat is in the "closed" position has a direct bearing on the ability of the engine to warm up. For suitable engine warm–up, coolant leakage past the thermostat valve must be at a minimum.

The rapid warm–up cooling system may use either of the two types of thermostats, which must generally be non–vented. This characteristic may allow the elimination of radiator shutters.

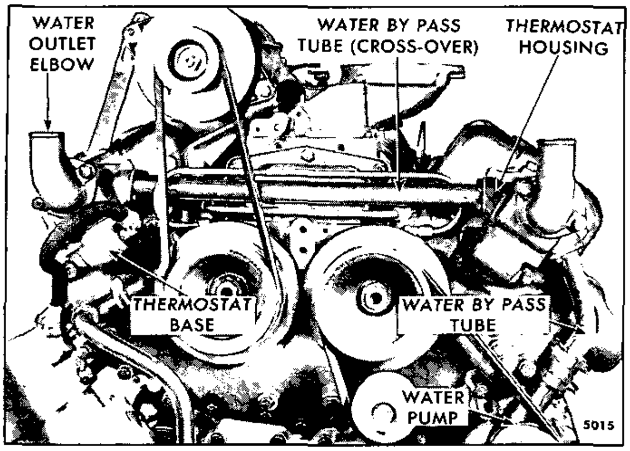


Fig. 2 – Thermostat Housings (6V Engine)

NOTICE: A 180° F (82° C) full blocking thermostat (no vent hole, valve face painted black) is currently used in rapid warm–up systems only, since these systems are externally vented to the top tank. Do not use non–vented thermostats in a conventional cooling system, since air binding of the cooling system and subsequent engine overheating and damage may occur.

The Bypass Circuit

The bypass circuit provides a route for coolant circulation before the thermostat opens. Coolant from the top of the engine flows back to the water pump without passing through the radiator or other heat exchanger. This flow of bypass coolant permits the engine to warm up to operating temperature while preventing "hot spots" which might damage the engine during this period of operation.

The bypass system on the V–type engine consists of a crossover tube connecting the two thermostat housings and an outlet tube attached between one thermostat housing and the water pump (Fig. 2). On the In–line engines, a bypass tube is attached between the thermostat housing and the water pump.

At coolant temperatures below approximately 170°F (77°C), the thermostat valve remains closed and blocks the flow of coolant through the radiator or heat exchanger. During this period, the coolant circulates through the cylinder block and head and then back to the suction side of the pump via the bypass tube. As the coolant temperature rises, the thermostat valve begins to open, restricting the bypass system and permits the coolant to circulate through the radiator or heat exchanger. When the valve is fully open, the bypass system of the V–type engine is completely blocked off and all of the coolant circulates through the radiator. However, with the valve fully opened in the In–line engine, a very small portion of the coolant will continue to circulate through the bypass tube, while the major portion will pass through the radiator.

A properly operating thermostat is essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range (see Section 13.3), remove and check the thermostat(s).

NOTICE: There are areas where approved fuel (less than 0.5% sulfur) is not commercially available or economically feasible to obtain. It is important to keep the engine cooling system temperature of these engines on the high side of normal to prevent the condensation of sulfur trioxide gas, which combines with combustion water to form sulfuric acid. Therefore, install a 180° or 190°F (82° or 88°C) temperature thermostat and modify the cooling system to provide rapid warm–up in order to maintain coolant temperature at a minimum of 175°F (80°C).

Remove Thermostat

1. Drain the cooling system to the necessary level by opening the drain valves.
2. Remove the hose connections between the thermostat housing water outlet elbow and the radiator or heat exchanger.
3. Loosen the bolts and remove the water outlet elbow from the thermostat housing on the In–line engine (Fig. 3). Take out the thermostat.
4. On the V–type engine, remove the crossover bypass tube which is located between the thermostat housings. Also disconnect the bypass tube between the water pump and the thermostat housing (Fig. 4). Remove the gaskets. Then loosen the bolts and remove the thermostat housings from their bases. Remove the thermostats and remove and discard the thermostat seals.

• Inspection

1. Check the thermostats.

   A defective thermostat which remains closed, or only partially open, will restrict the flow of coolant and cause the engine to overheat. A thermostat which is stuck in a full open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold engine operation will result in excessive carbon deposits on the pistons, rings and valves. To check the operation of thermostats, refer to Section 5.0.

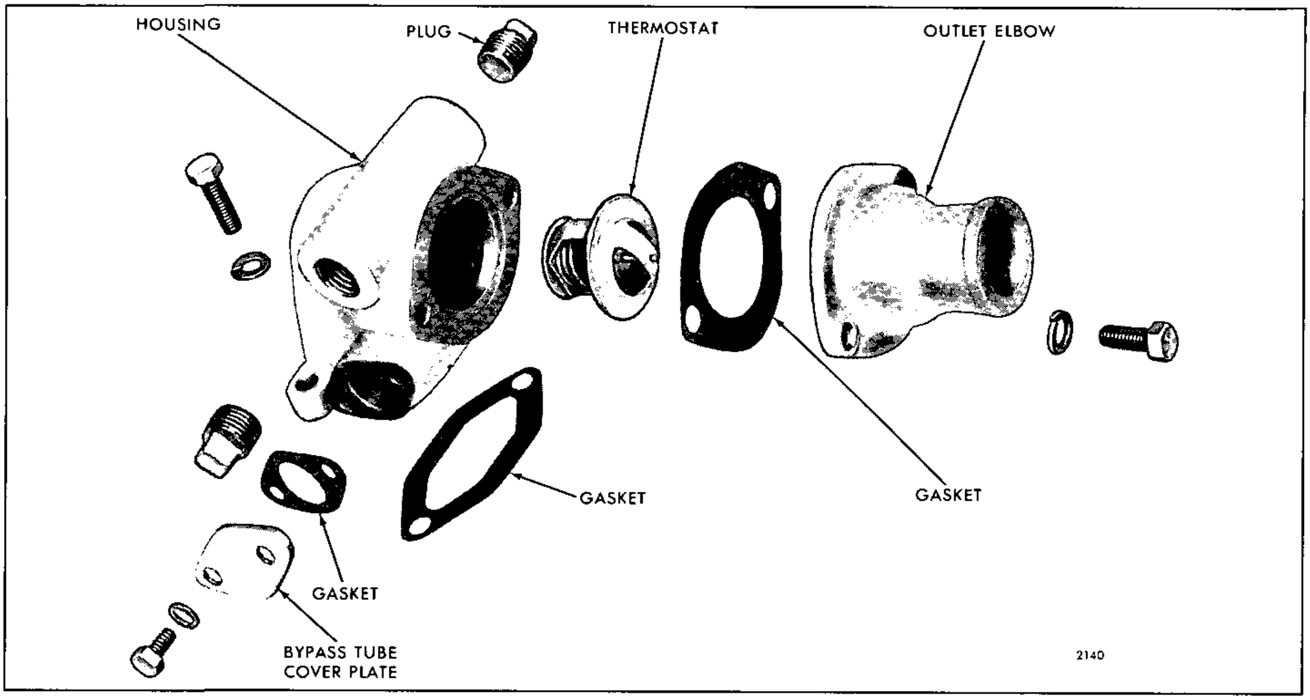


Fig. 3 – Thermostat Housing Details and Relative Location of Parts (In–Line Engine)

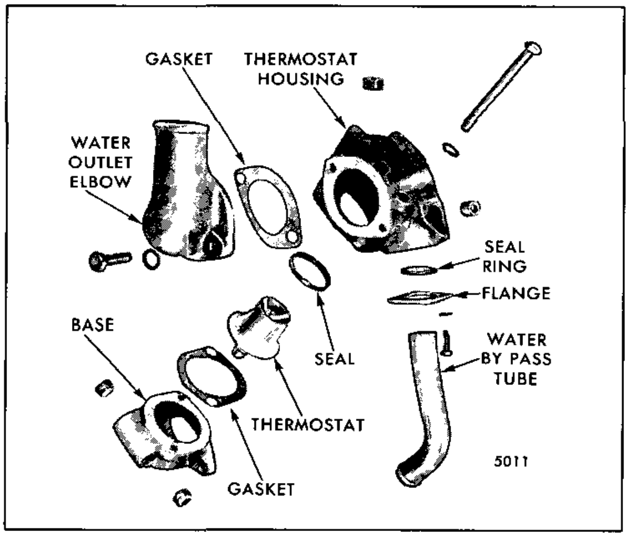


Fig. 4 – Thermostat Housing Details and Relative Location of Parts (V–Type Engine)

2. Check the thermostat flange counterbore in the housing and base or the water outlet elbow. Make sure it is clean and free from any obstructions that could prevent full seating of the flange.

3. Check the thermostat housing cover bypass cast seal ring. Check for wear and proper alignment of thermostat. Replace the cover if the thermostat will not properly block off the bypass cavity during full–open thermostat operation.

4. Check the bleed hole in the thermostat housing to make sure it is open (Fig. 5).

   The early 6V–53 themostat housing had three bleed holes. Current housings have one bleed hole. If an excessively long warm up period is encountered with the former thermostat housing (three bleed holes), plug two of the bleed holes with No. 4 drive screws.

   Drill a 3/32 diamter hole in the thermostat housing used on In–line industrial engines built prior to serial number 2D–603, 3D–011 or 4D–094 (refer to Fig. 6). This will provide a coolant drain hole for the bypass cavity in the housing.

Install Thermostat

Refer to Figs. 3 and 4 and install the thermostat(s) as follows:

IN–LINE ENGINE:

1. Place a new gasket on the thermostat housing.
2. Insert the thermostat into the housing.
3. Install the water outlet elbow and secure it to the housing with two bolts and lock washers.

4. Connect the hose from the radiator or heat exchanger to the water outlet elbow. Align and tighten the hose clamps.

V–TYPE ENGINE:

1. Install new seals in the thermostat housings. Position the seals so the lips face away from the thermostats. Press the seals in with seal installer J 22091 and handle J 7079–2.

2. Place a new gasket on each thermostat housing base.

3. Insert a thermostat in each base.

4. Install the thermostat housings and secure the housings with bolts and lock washers. *Exercise care to prevent damage to the thermostat seals.*

5. Place new seals on the crossover bypass tube, then reinstall the tube.

6. Use new gaskets and attach the water outlet elbows to the thermostat housings. Secure the elbows with bolts and lock washers.

7. Place a new seal on the upper end of the bypass tube and install the tube between the thermostat housing and the water pump.

8. Install the hoses between the radiator or heat exchanger and the water outlet elbows and secure them with the hose clamps.

After the thermostats have been installed, close all of the drain cocks and fill the cooling system. Vent the system as outlined in Section 5. Then start the engine and check for leaks.

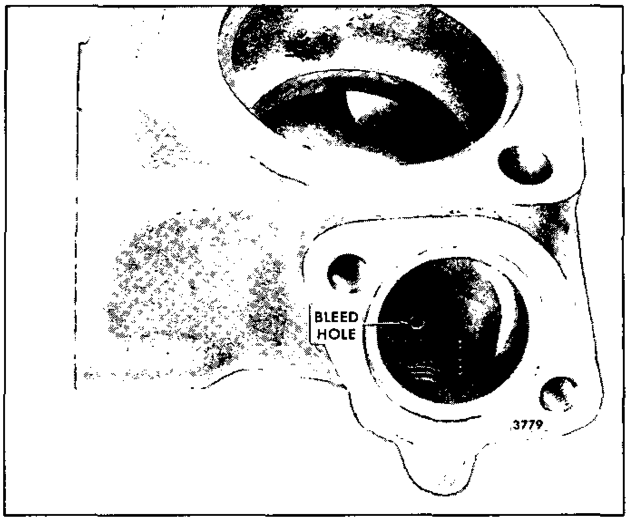


Fig. 5 – Bleed Hole in Thermostat Housing (V–Type Engine)

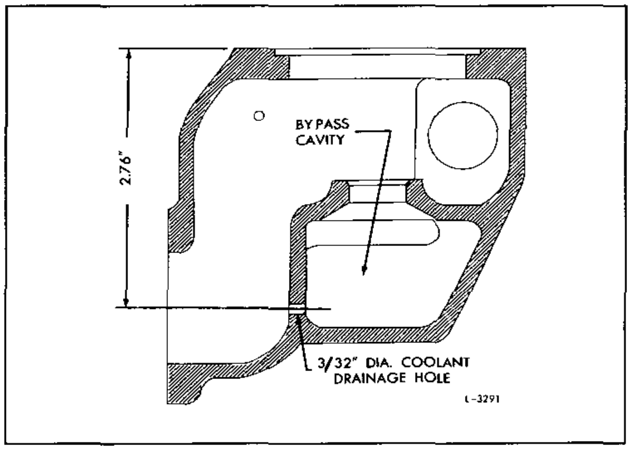


Fig. 6 – Cross–Section of Thermostat Housing (Early Industrial In–line Engine)

RADIATOR

On some engines the temperature of the coolant circulating through the engine is lowered by the action of the radiator and the fan. The radiator is mounted in front of the engine (Fig. 1) so that the fan will draw air through it, thereby lowering and maintaining the coolant temperature to the degree necessary for efficient engine operation.

The life of the radiator will be considerably prolonged if a recommended type coolant is used (refer to Section 13.3).

To increase the cooling efficiency of the radiator, a metal shroud is placed around the fan. The fan shroud must be fitted airtight against the radiator to prevent recirculation of the hot air drawn through the radiator. Hot air which is permitted to pass around the sides or bottom of the radiator and is again drawn through the radiator will cause overheating of the engine.

Another cause of overheating is slippage of the fan drive belts which is caused by incorrect belt tension, worn belts or worn fan belt pulley grooves, or the use of fan belts of unequal length when two or more belts are used. The belt tension and condition of the belts should be checked periodically (refer to *Preventive Maintenance*, Section 15.1). A faulty fan, inoperative or misadjusted shutterstats could also cause an engine to overheat.

A radiator that has a dirty, obstructed core or is leaking, a leak in the cooling system, or an inoperative *thermostat will also cause the engine to overheat.* The radiator must be cleaned, the leaks eliminated, and defective thermostats replaced immediately to prevent serious damage from overheating.

- **NOTICE: The use of winterfronts (cardboard, canvas, etc.) is not recommended with any DDC engine installation.** Their use can result in excessive engine coolant, oil, and charge air temperatures. This can lead to turbocharger surge, poor fuel economy, loss of power, and reduced engine life. Winterfronts may also put abnormal stress on fan and fan drive components, creating the potential for premature malfunction and/or damage.

The external cleanliness of the radiator should be checked if the engine overheats and no other causes are apparent.

Cleaning Radiator

The radiator should be cleaned whenever the foreign deposits are sufficient to hinder the flow of air or the transfer of heat to the air. In a hot, dusty area, periodic cleaning of the radiator will prevent a decrease in efficiency and add life to the engine.

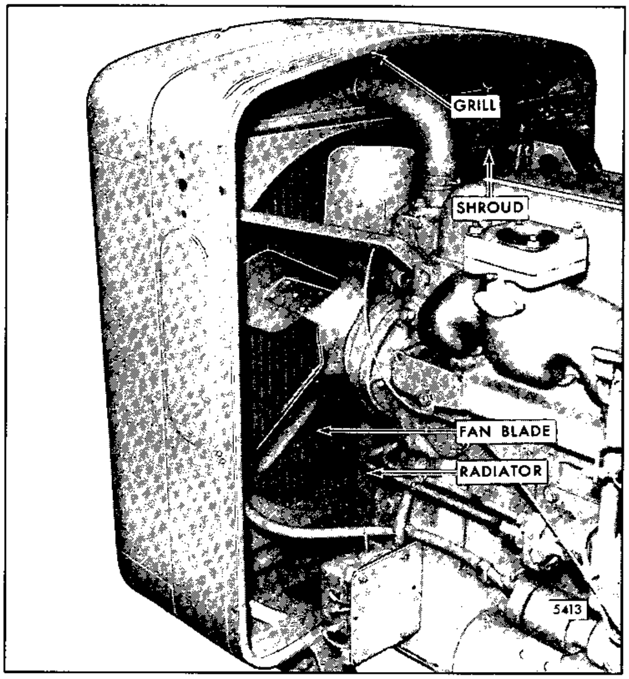


Fig. 1 – Typical Radiator Mounting (In-Line Engine)

The fan shroud and grill should be removed, if possible, to facilitate the cleaning of the radiator core.

An air hose with a suitable nozzle is often sufficient to remove loose dust from the radiator core.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Occasionally, however, oil may be present requiring the use of a solvent, such as mineral spirits, to loosen the dirt. *The use of gasoline, kerosene or fuel oil is not recommended as a solvent.* A spray gun is an effective means of applying the solvent to the radiator core. Use air to remove the remaining dirt. Repeat this process as many times as necessary, then rinse the radiator with clean water and dry it with air.

To avoid damage to the radiator fins, do not use high air or water pressure.

CAUTION: Provide adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray.

Another method of cleaning the radiator is the use of steam or a steam cleaning device, if available. If the foreign deposits are hardened, it may be necessary to apply solvents.

The scale deposit inside the radiator is a result of using hard, high mineral content water in the cooling system. The effect of heat on the minerals in the water causes the formation of scale, or hard coating, on metal surfaces within the radiator, thereby reducing the transfer of heat. Some hard water, instead of forming scale, will produce a silt–like deposit which restricts the flow of water. This must be flushed out at least twice a year — more often if necessary.

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as sal–ammoniac, at the specified rate of 1/4 pound per each gallon of radiator capacity, should be added to the coolant water in the form of a dissolved solution while the engine is running. Operate the engine for at least fifteen minutes, then drain and flush the system with clean water.

Other flushing compounds are commercially available and should be procured from a reliable source. Most compounds attack metals and should not remain in the engine for more than a few minutes. A neutralizer should be used in the cooling system immediately after a descaling solvent is used.

For extremely hard, stubborn coatings, such as lime scale, it may be necessary to use a stronger solution. The corrosive action of a stronger solution will affect the thin metals of the radiator, thereby reducing its operating life. A complete flushing and rinsing is mandatory and must be accomplished skillfully.

After the solvent and neutralizer have been used and the cooling system is flushed, completely drain the entire system again and fill it with a recommended coolant (refer to *Engine Coolant* in Section 13.3). After filling the cooling system, inspect the radiator and engine for water leaks.

When draining or filling, the cooling system must be vented.

After the radiator core has been thoroughly cleaned and dried, reinstall the fan shroud and grill, if removed.

Remove Radiator

1. Remove the radiator filler cap and open the drain cock to drain the cooling system. Also open the drain cock on the oil cooler and the engine block.

2. Remove the bolts, lock washers and nuts which attach the fan guards to the fan shroud.

3. Loosen the hose clamps at the radiator inlet hose and remove the hose.

4. Loosen the hose clamps at the radiator outlet hose and remove the hose.

5. Use a chain hoist and a suitable lifting device (through the filler neck or otherwise) and draw the hoisting chain taut to steady the radiator.

6. Remove the bolts, lock washers, plain washers, nuts and bevel washers (if used) which attach the radiator shell to the engine base.

   NOTICE: Since the shroud is very close to the tips of the fan blades, to prevent damage to these parts great care must be exercised whenever the radiator is removed.

7. Lift the radiator enough to clear the engine base and move it directly away from the engine.

8. Remove the fan shroud and the radiator core by removing the bolts securing them in place.

Inspection

Clean all radiator parts thoroughly, removing dirt, scale and other deposits.

Examine the radiator for cracks or other damage. The core fins should be straight and evenly spaced to permit a full flow of cooling air. The core tubes should be clean inside and outside and have no leaks.

If repainting the radiator core becomes necessary, it is recommended that a thin coat of dull black radiator paint or another high quality flat black paint be used. Ordinary oil paints have an undesirable glossy finish and do not transmit heat as well.

Check all radiator hoses and clamps. Replace cracked and deteriorated hoses and damaged clamps.

Install Radiator

Assemble the radiator, grill and shroud. Then mount the assembly on the engine base by reversing the procedure given for removal.

Check for clearance between the tips of the fan blades and radiator shroud after the radiator is in place. There must be sufficient clearance or damage to the fan and shroud will result when the engine is started. Use shims between the radiator and base, if necessary, to obtain the proper clearance.

CROSS–FLOW DESIGN RADIATOR

Certain 6V–53 on–highway vehicle engines incorporate a cooling system radiator of a cross–flow design rather than the conventional down–flow design.

As the name implies, a cross–flow radiator has a core of horizontally positioned tubes and coolant flow moves across rather than down the radiator.

Two reasons for using the cross–flow design radiator are:

1. The reduced height of the radiator permits a lower hood line design, thus providing better road visibility.
2. The area ahead of the engine crankshaft and below the radiator is open for mounting a power take–off unit, if desired.

The intent here is to describe briefly how the cross–flow radiator functions and to identify some of the components unique in the cross–flow system.

One such component is a Y–shaped device called an aspirator (Fig. 2) which is mounted externally on the filler cap side of the radiator and serves to rid the cooling system of air. The aspirator directs coolant under pressure through a venturi where entrapped air inside the radiator is picked up and moved to the supply chamber of the radiator where it is vented. The coolant line providing the drive flow originates at the engine thermostat housing. This hookup provides a flow of coolant to the aspirator regardless of whether the thermostat is open or closed. As the coolant flow passes through the aspirator, its action pulls coolant and any air that is present from the top of the radiator core outlet chamber into an internal "U" tube which vents near the filler cap inside the radiator supply chamber to complete the deaeration process. This "U" tube insures that the entire cooling circuit, other than the supply chamber, remains completely full when the engine is stopped. Also, it keeps the coolant from seeking a common level throughout the system and, thereby, eliminates an aerated system at the next engine start–up.

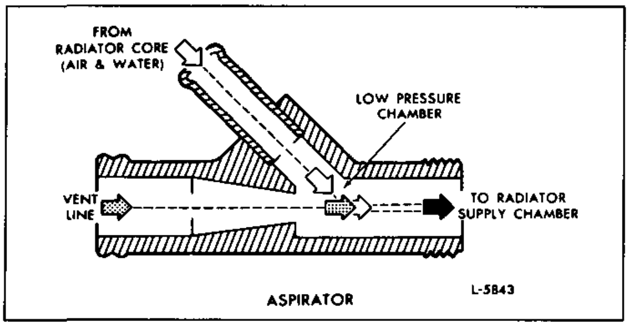


Fig. 2 – Aspirator for Cross–Flow Design Radiator

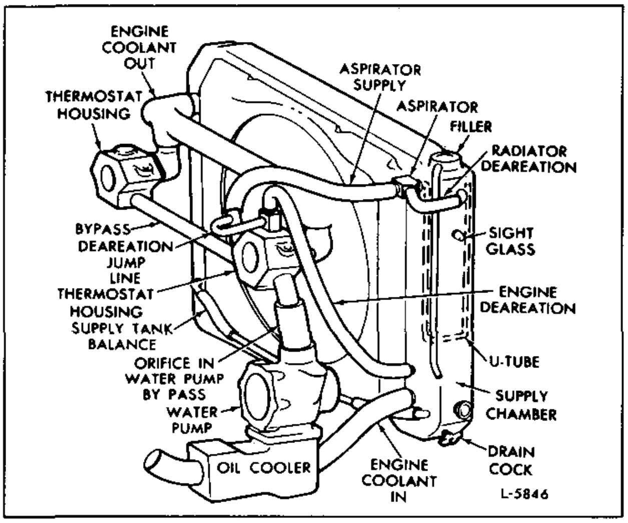


Fig. 3 – Cross–Flow Design Radiator

In order to provide adequate coolant flow through the engine deaeration line when the thermostat is closed, a restricting orifice is used in the engine water pump bypass (Fig. 3). This orifice is 5/8" I.D. and is brazed into the upper end of the water bypass tube that connects the right–hand thermostat housing to the water pump; thus, it becomes a permanent part of the water bypass tube assembly and *must* be used for adequate system performance.

Properly installed hose connections are required for adequate cross–flow radiator efficiency. Figure 3 illustrates the proper hose connections for the 6V–53 installation.

The cross–flow cooling system should always be drained at the radiator drain cock. This will insure that both the radiator and internal "U" tube is empty. If the "U" tube is not emptied, refilling the system will prove difficult.

Due to the design of the cross–flow radiator, air may be trapped inside of the radiator during the fill process resulting in a false coolant level reading. Therefore, after filling the cooling system, the engine should be run approximately ten minutes at 1200–1400 rpm so that any entrapped air can be vented. Generally, additional coolant (approximately 3 to 4 quarts or 2.8 to 3.8 liters) will be required to bring the coolant to the proper level.

For efficient operation of the cross–flow radiator system, it is important that no leak exists between the radiator core and the supply tank. If an internal leak has developed between the radiator core and the supply tank, it can cause the cooling system to become aerated at low speed and following engine shut down. The radiator should be tested periodically for possible internal leaks. To determine if a leak is present, proceed as follows:

1. Remove the radiator cap and run the engine for approximately ten minutes at high idle to completely deaerate the cooling system. While the engine is running, add additional coolant to the supply chamber to bring the coolant level to the bottom of the filler neck.

2. Stop the engine and drain 4 quarts (3.8 liters) of coolant from the radiator.

3. Start and run the engine at high idle for approximately ten minutes and observe the coolant level.

4. Stop the engine and again observe the coolant level. If the coolant rises substantially in the supply tank, an internal leak is present and immediate corrective action should be taken to repair the leak. If the coolant level remains constant or falls, the system is satisfactory.

5. After the test is completed, refill the cooling system to the proper coolant level.

If the leak situation is not corrected, the engine will be operating with an aerated coolant for abnormal periods of time which could lead to an engine failure.

COOLANT PRESSURE CONTROL CAP

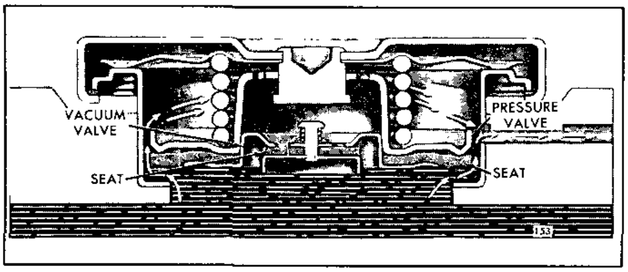


Fig. 1 – Pressure Control Cap (Pressure Valve Open)

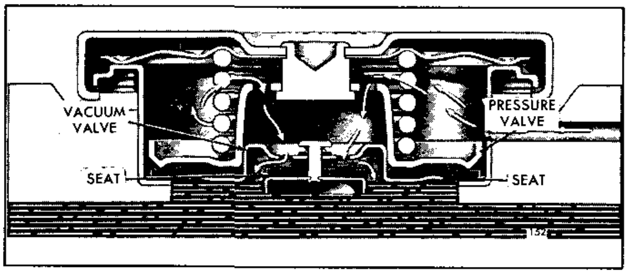


Fig. 2 – Pressure Control Cap (Vacuum Valve Open)

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap, with a number "7" stamped on its top, is designed to permit a pressure of approximately seven pounds (48 kPa) in the system before the valve opens. The cap with a number "9" stamped on its top, is designed to permit a pressure of approximately nine pounds (62 kPa) in the system before the valve opens. This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools.

CAUTION: Use extreme care while removing the coolant pressure control cap. Remove the cap *slowly* after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically with tester J 22460–01 for proper opening and closing pressures. If the pressure valve does not open between 6.25 psi (43.1 kPa) and 7.5 psi (51.7 kPa) or the vacuum valve is not open at .625 psi (4.3 kPa) – (differential pressure), replace the pressure control cap.

It is recommended that all 53 on–highway vehicle engines use a minimum 9 psi (62 kPa) pressure control cap. If the pressure valve does not open between 8 psi (55 kPa) and 10 psi (69 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) – (differential pressure), replace the pressure control cap.

ENGINE COOLING FAN

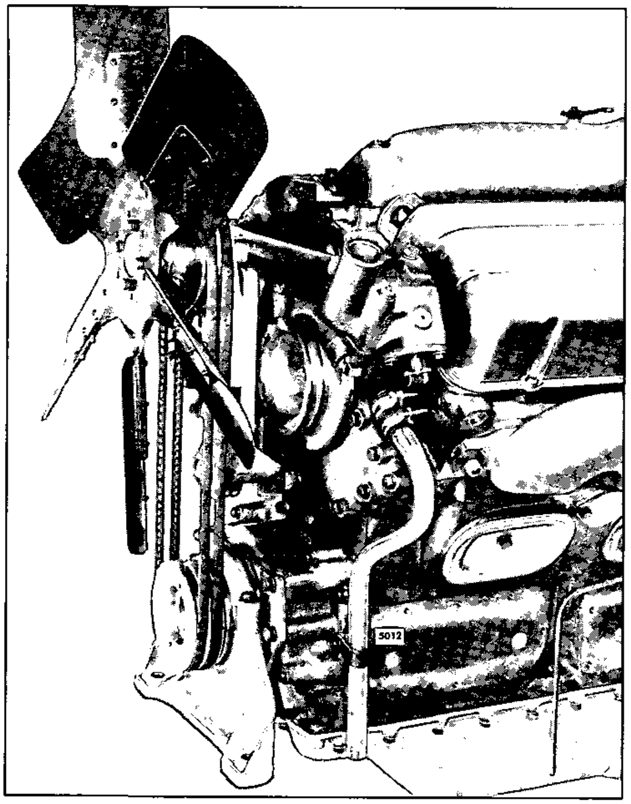


Fig. 1 – Belt–Driven Fan Mounting (V–Type Engine)

The engine cooling fan is driven by a pair of V–drive belts from the crankshaft pulley (Fig. 1) or driven directly by the crankshaft (Fig. 2). Because of high vibration loads on certain applications, a new 22" five blade fan with a thicker spacer is now being used on the In–line 53 engines as required. This is effective with engine serial number 4D–154007. The former and new fan assemblies are interchangeable on an engine, but only the new fan assembly is serviced.

Effective with engine serial numbers 2D–28185, 3D–66957 and 4D–68816, new fan hub assemblies are being used on the In–line engines. The new assemblies are similar to the integral cast shaft and bracket design, with tapered roller bearings, currently used on the V–type engines (Fig. 5). A new pulley hub assembly is now being used on certain four and six cylinder 53 Series engines to extend operational life under severe dirt conditions. It includes a front ball bearing and a rear roller bearing along with a hub cap (with relief valve), a dust cap and a grease fitting in the fan pulley hub (Fig. 8).

The belt–driven fan is bolted to a combination fan hub and pulley which turns on a sealed ball bearing assembly (former In–line engines), two tapered roller bearings (present V–type and In–Line engines) or a front ball bearing and a rear roller bearing (new 4–53 and 6V–53 engines). The crankshaft driven fan is bolted to the crankshaft pulley.

Lubrication

The sealed ball bearing, used in the fan hub assembly shown in Fig. 3, is pre–lubricated and requires no further lubrication.

Tapered roller bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Section 15.1 for the maintenance schedule.

Fan Belt Adjustment

Adjust the fan belts periodically as outlined in Section 15.1.

Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core.

NOTICE: Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core.

Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the fan belts and fan guards.
2. Remove the attaching bolts and lock washers and remove the fan and spacer (if used).

   If insufficient clearance exists between the fan and radiator, remove the fan, hub and adjusting bracket as an assembly.
3. Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then, withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

Disassemble Hub and Adjusting Bracket

IN–LINE ENGINES (Ball Bearing Type Hub):

1. Refer to Fig. 3 and measure the distance between the rear face of the rim on the pulley and the rear face (machined) of the fan adjusting bracket. Record this measurement for reassembly purposes.
2. Remove the fan hub from the shaft with a puller as shown in Fig. 4.

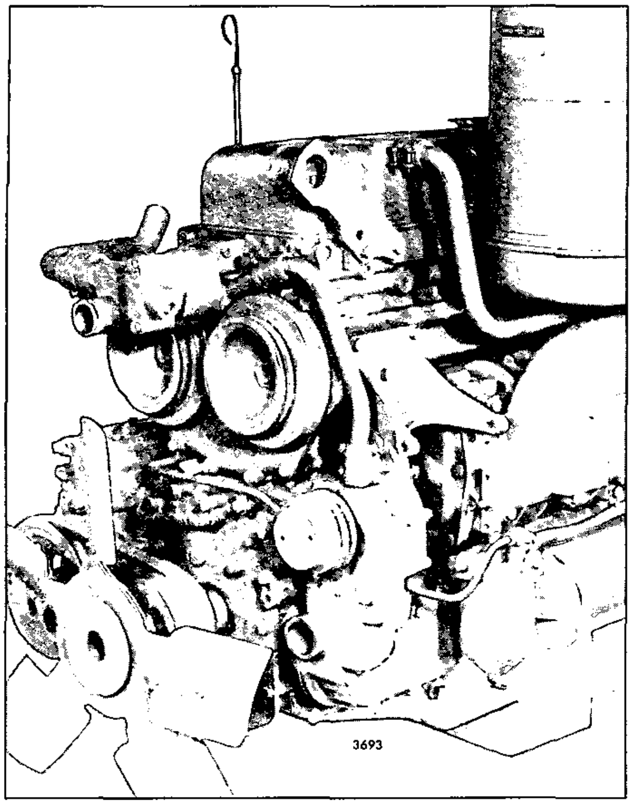


Fig. 2 – Crankshaft–Driven Fan Mounting (In–Line Engine)

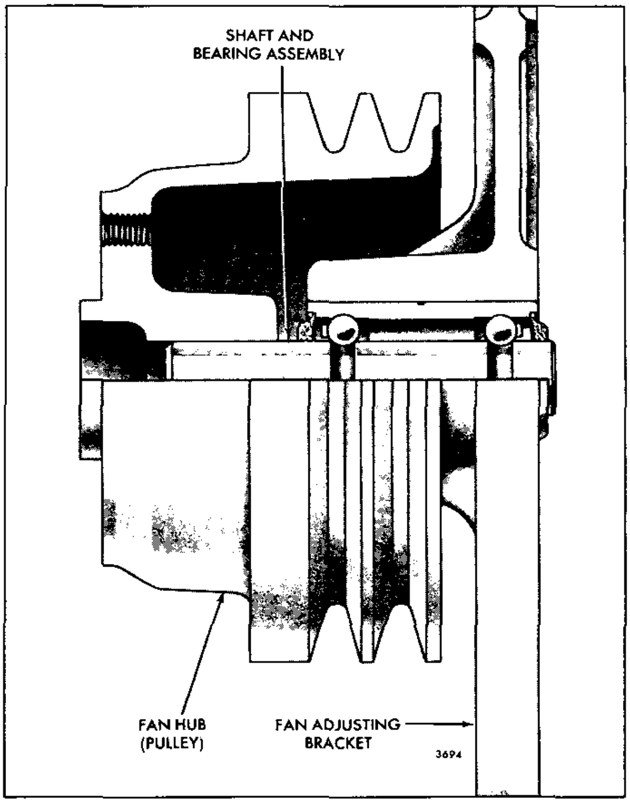


Fig. 3 – Ball Bearing Type Fan Hub Assembly (In–Line Engine)

3. Place the bracket assembly in an arbor press. Then, place a suitable sleeve over the shaft and against the outer race of the bearing and press the bearing and shaft assembly from the bracket.

NOTICE: *Damage to the bearing will result if force is applied to the shaft.*

IN–LINE ENGINES (Roller Bearing Type Hub):

1. Refer to Fig. 5 and remove the fan hub cap.
2. Remove the hub bolt and washer.
3. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.
4. Remove the oil seal and bearing from the fan hub.
5. Remove the bearing spacer, shims and grease retainer.

4–53 and V–TYPE ENGINES:

1. Remove the fan hub cap (if a spacer and cap assembly were not used).

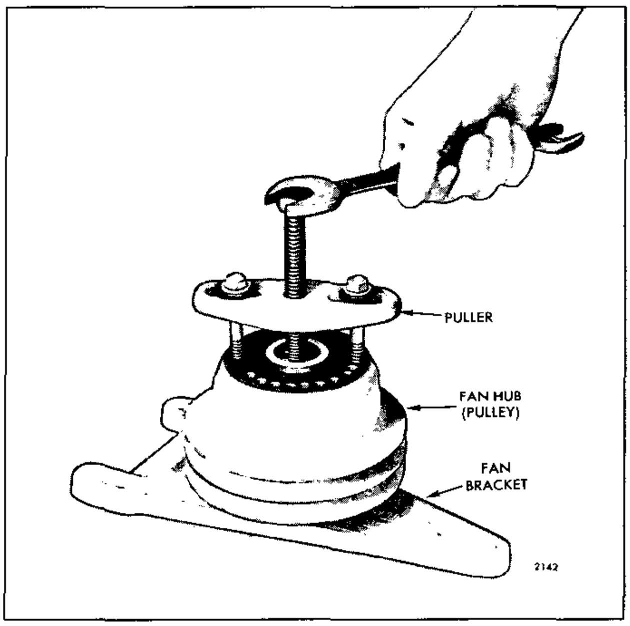


Fig. 4 – Removing Fan Hub (Pulley)

2. Remove the hub retaining cotter pin, nut and washer (Fig. 6) or the bolt and special washer (Fig. 7 and 8). Also, remove the shims if the former type fan hub assembly illustrated in Fig. 7 is used.

3. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

4. Remove the seal and bearings from the fan hub.

5. Remove the bearing spacer (Fig. 7 and 8) and shims (if the current type hub assembly is used).

Inspection

Clean the fan and related parts with clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

NOTICE: To avoid bearing damage, do not wash the permanently sealed bearing which is used in the In-line engine roller bearing hub assembly. Wipe the bearing and shaft assembly with a clean lintless cloth.

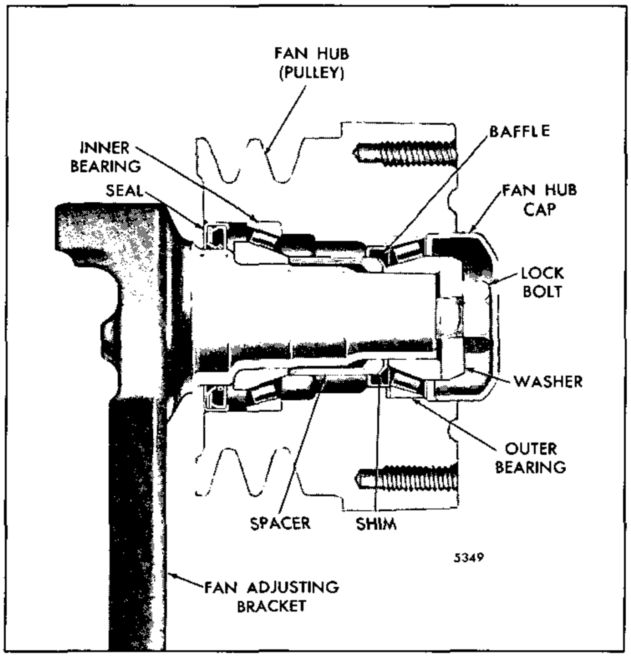


Fig. 5 – Shaft Type Fan Hub Assembly (6V Engine)

Hold the inner race (shaft of sealed ball bearing assembly) and revolve the outer race of the bearing slowly by hand. If rough or tight spots are detected, replace the bearing.

The current fan shaft rear bearing inner race should be inspected for any measurable wear. Replace the inner race if the outer diameter is less than 1.7299". *The inner and outer races are only serviced as a rear roller bearing assembly.*

When installing the rear bearing inner race, press it on the shaft and position it 1.35" to 1.37" from the end of the shaft.

Check the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

New .500" thick and .800" thick fan hub spacers and a new fan hub cap replace the former spacer and cap assemblies to provide spacers compatible with the six bolt hole mounting fan hub assemblies. The spacers (individually or in combination) also provide a means for setting the different clearances between the back of the fan blades and front groove of the crankshaft pulley.

The spacers have a flange on one side that serves as a pilot for the fan as well as a spacer pilot for the second spacer when two or more spacers are used together.

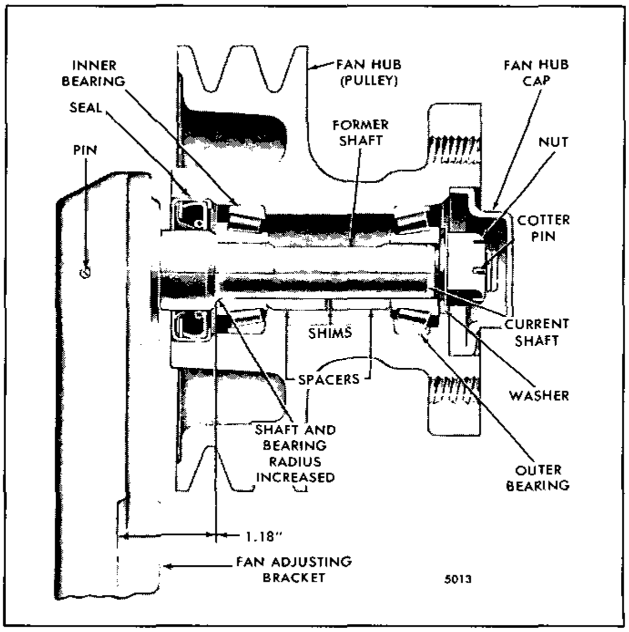


Fig. 6 – Shaft Type Fan Hub Assembly (6V Engines)

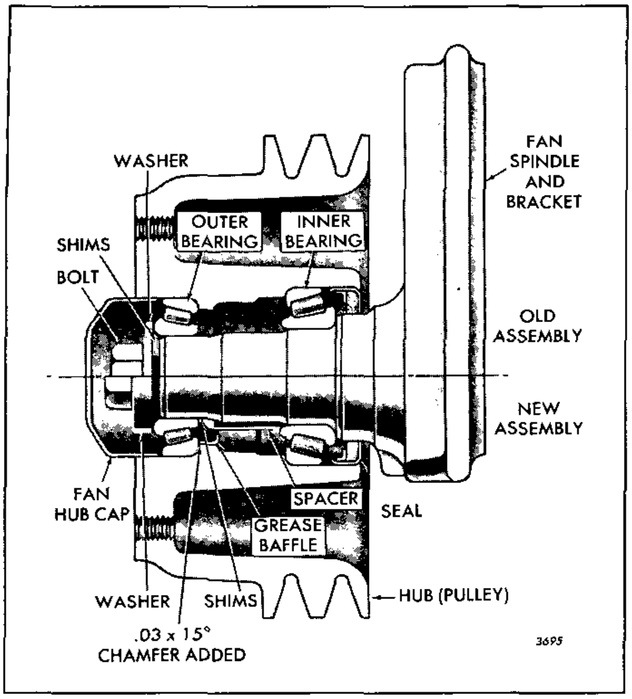


Fig. 7 – Spindle Type Fan Hub Assembly (6V and 8V Engine)

EXAMPLE: A former 1.800" thick spacer and cap assembly have been replaced by two .500" thick spacers, one .800" thick spacer and the new fan hub cap.

When replacing the former fan hub spacer, be sure to include the new cap.

The fan hub assembly illustrated in Fig. 6 has been revised. The revisions consist of an increase in the bearing inner race and shaft bearing radii, a hardened hub retaining *nut and washer and the addition of spacers and shims on the* shaft between the bearings. This type fan hub assembly should be rebuilt with the current parts, especially where the former undercut shaft is used. The current spacers and shims cannot be used with the former shaft.

To replace the shaft, remove the groove pin and press the shaft from the adjusting bracket. Press the new shaft in the bracket to the dimension shown in Fig. 5. Then, drill the shaft, using the hole in the bracket as a guide, and install a groove pin.

The spindle–type fan hub assembly illustrated in Fig. 7 has also been revised. A bearing spacer has been added and a new outer bearing, which provides a closer fit on the shaft, replaces the old. A baffle has also been added to retain the grease and assure lubrication at the outer bearing. *To facilitate installation of the grease baffle,* a .030" by 15° chamfer has been added to the bore in the pulley.

The tapped hole in the end of the shaft has been counterbored and increased in depth from 1.000" to 1.260". A longer hub retaining bolt and a .320" thick washer replaces the former bolt and 1/8" thick washer.

New shims, assembled between the bearing spacer and the inner race of the outer bearing, provide .001" to .006" end play. The former shims, which were assembled between the hub retaining washer and the end of the shaft, provide .002" to .004" end play.

When service is required on the spindle–type shaft, it *should be rebuilt with the new components.*

Fan hubs equipped with roller bearings (except the sealed type in Fig. 3) may be modified by adding a grease fitting (refer to Section 5.0).

Assemble Hub and Adjusting Bracket

A new, heavy–duty shaft and bearing assembly is now used for high–mounted fan applications. This assembly incorporates both ball and roller bearings (Fig. 11). The former assembly contained two rows of ball bearings. The new shaft and bearing assembly can be identified by the designation "HR–803" stamped on the front of the shaft.

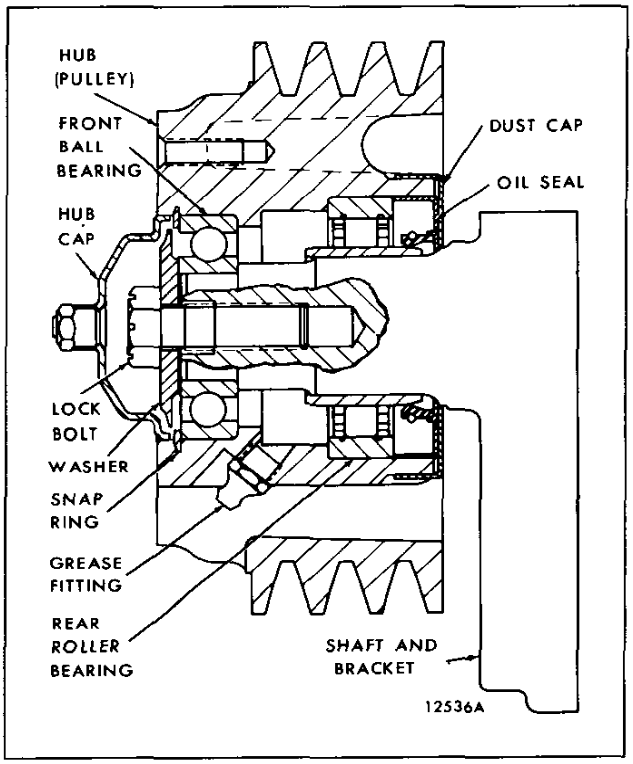


Fig. 8 – Shaft Type Fan Hub Assembly (4–53 and 6V–53 Engines)

Both former and new shaft and bearing assemblies are completely interchangeable, and only the new will be available for service.

Apply Loctite "601" or equivalent to the bearing shaft and the bearing case when rebuilding the fan hub assembly.

IN–LINE ENGINES (Ball Bearing Type Hub):

Refer to Figs. 3 and 9 and assemble the fan hub and adjusting bracket as follows:

1. Press the shaft and bearing assembly into the adjusting bracket by applying pressure on the outer race of the bearing, using a suitable sleeve, until the bearing is flush with the pulley end of the bracket.

2. Measure the shaft diameter and the pulley bore. It is important that a .001″–.002″ press fit be maintained. Then, support the bearing end of the shaft and press the fan hub (pulley) on the shaft to the original dimensions taken during disassembly. This will assure proper alignment and clearance of the parts.

The shaft and bearing assembly are permanently sealed and require no lubrication.

IN–LINE ENGINES (Roller Bearing Type Hub):

Assemble the fan hub and spindle shown in Fig. 5 as follows:

1. Apply Texaco Premium RB grease or an equivalent Lithium base multi–purpose grease to the rollers of both bearings before installing them in the fan hub (pulley).

2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.

3. Install a new seal with the felt–side flush with the outer edge of the hub.

4. Place the hub over the spindle and install the bearing spacer.

5. Pack the cavity approximately 1/4 full with grease and install the grease baffle.

6. Place the shims against the bearing spacer. Then, install the outer bearing with the protruding face of the inner race facing outward from the hub.

7. Place the retaining washer with the breakout side toward the bearing. Install and tighten the bolt to 83–93 lb–ft (113–126 N·m) torque while rotating the pulley.

8. Check the end play in the assembly with the spindle (shaft) in a horizontal position. The end play must be within .001″ to .006″. If necessary, remove the bolt, washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015″, .020″ and .025″ thickness. Then, reassemble the fan hub and check the end play.

9. Fill a new fan hub cap 3/4 full of grease and install it in the end of the fan hub (pulley).

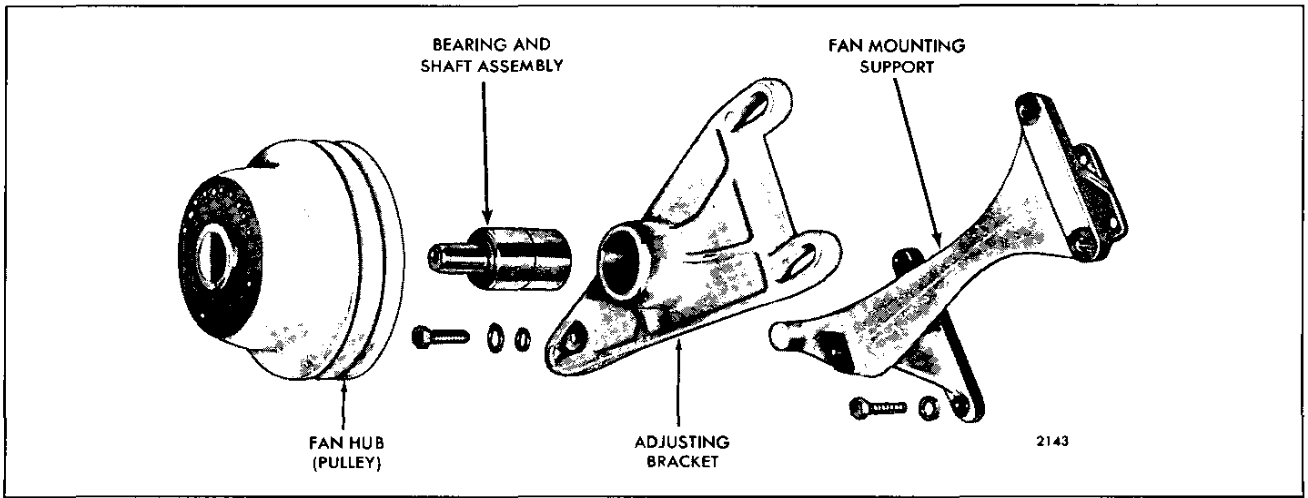


Fig. 9 – Typical Fan Hub and Adjusting Bracket Details and Relative Location of Parts (In–Line Engine)

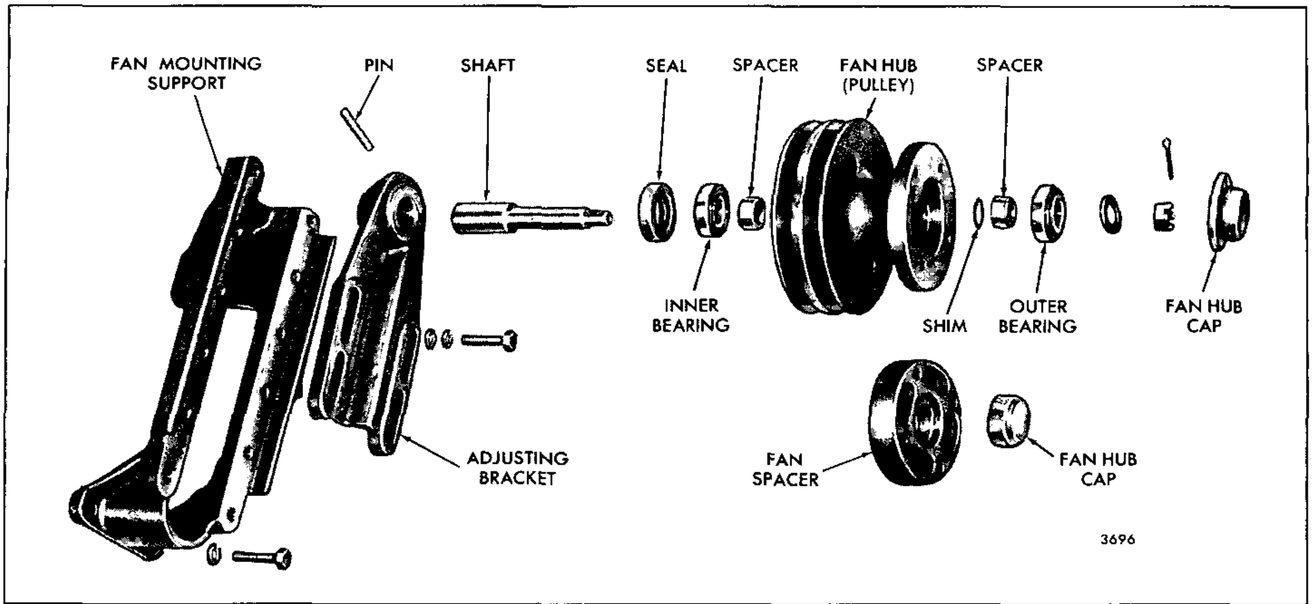


Fig. 10 – Typical Fan Hub, Shaft and Adjusting Bracket Details and Relative Location of Parts (6V Engine)

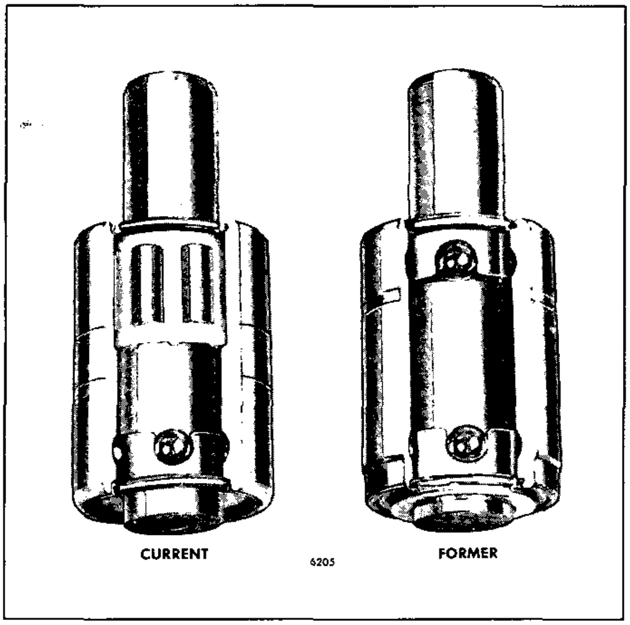


Fig. 11 – Heavy–Duty Shaft and Bearing Assembly

V–TYPE ENGINE:

Assemble the fan hub, shaft and adjusting bracket shown in Figs. 6 and 10 as follows:

1. Apply Texaco Premium RB grease or an equivalent Lithium base multi–purpose grease to the rollers of both bearings before installing them in the fan hub (pulley).
2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.
3. Install a new seal with the lip of the seal facing toward the bearing. Coat the lip of the seal lightly with grease.
4. Slide the spacers and shims on the shaft (Fig. 6).

   It may be necessary to install as many as three .005" and three .010" shims between the spacers on a current shaft incorporated in a former fan hub to achieve the required .001" to .005" end play.
5. Place the hub over the shaft and pack the cavity approximately 1/2 full with grease. Then, install the outer bearing with the protruding face of the inner race facing outward from the hub.
6. Secure the hub assembly with the washer and 1/2"–20 nut. Tighten the nut to 35–40 lb–ft (47–54 N·m) torque.

   NOTICE: Enough shims must be provided to avoid loading directly through the bearing rollers when the nut is torqued. The pulley must turn freely after the nut is tight.
7. Check the bearing end play. If the end play is not within the specified limits (.001" to .005"), remove the hub, add or remove shims and repeat Steps 5 and 6.
8. Fill a new fan hub cap 1/2 full of grease and install it in the end of the fan hub (pulley).

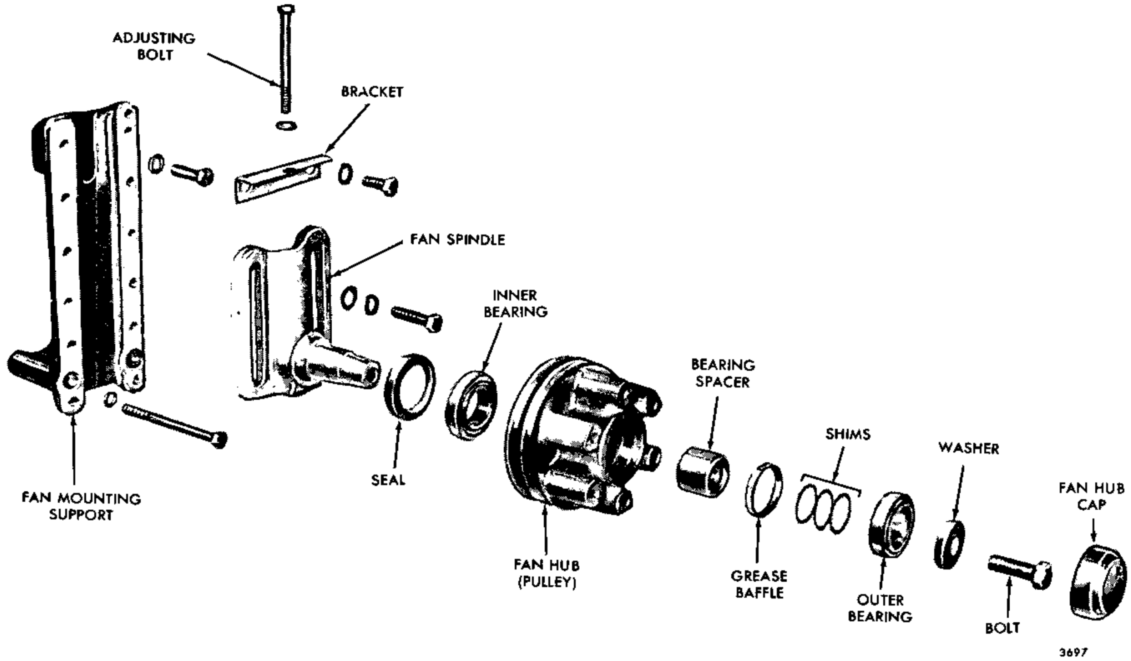


Fig. 12 – Typical Fan Hub and Spindle Details and Relative Location of Parts (6V and 8V Engine)

Assemble the fan hub and spindle shown in Figs. 7 and 12 as follows:

1. Apply Texaco Premium RB grease or an equivalent Lithium base multi–purpose grease to the rollers of both bearings before installing them in the fan hub (pulley).
2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.
3. Install a new seal with the felt–side flush with the outer edge of the hub.
4. Place the hub over the spindle and install the bearing spacer.
5. Pack the cavity approximately 1/4 full with grease and install the grease baffle.
6. Place the shims against the bearing spacer. Then, install the outer bearing with the protruding face of the inner race facing outward from the hub.
7. Secure the hub with the retaining washer and bolt. Tighten the 1/2"–20 bolt to 83–93 lb–ft (113–126 N·m) torque while rotating the pulley.
8. Check the end play in the assembly with the spindle (shaft) in a horizontal position. The end play must be within .001" to .006". If necessary, remove the bolt, washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015", .020" and .025" thickness. Then, reassemble the fan hub and check the end play.
9. Fill a new fan hub cap 3/4 full of grease and install it in the end of the fan hub (pulley).

4–53 and 6V–53 ENGINES (Front Ball and Rear Roller Bearing):

Assemble the new pulley hub as follows (Fig. 8).

1. Apply Texaco Premium RB grease or an eqivalent Lithium base multipurpose grease to the front ball bearings and the rollers of the rear bearing, before installing them in the pulley hub. *Do not overgrease.*
2. Install the front ball bearing against the shoulder counterbore in the pulley hub. Then, install the snap ring in the pulley hub.
3. Install the rear roller bearing outer ring and roller assembly against the shoulder in the counterbore of the pulley hub.

4. Install a new oil seal with rubber side flush with the outer edge of the hub.

5. Install the dust cap (if used) over the oil seal in the hub.

6. Place the shaft and bracket on wood blocks setting on the bed of an arbor press. Then, press the rear bearing inner ring or race onto the fan shaft.

7. Pack the cavity 3/4 full with Texaco Premium RB grease.

8. Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pully hub shaft.

9. Secure the hub with the washer and 1/2″–20 lock bolt. Tighten the bolt to 83–93 lb–ft (113–126 N·m) torque while rotating the pulley hub.

10. Fill a new fan hub cap 3/4 full of grease and install it in the end of the pulley hub.

Install Fan, Hub and Adjusting Bracket

1. Attach the fan hub and adjusting bracket assembly to the support bracket on the engine with bolts, lock washers and plain washers. Do not tighten the bolts until the fan belts are installed.

2. Install the drive belts and adjust the belt tension as outlined in Section 15.1. If used, install the adjusting bracket, bolt and plain washer shown in Fig. 12.

3. Install the fan (and fan spacer and cap, if used) on the hub and secure it with the 5/16″–18 bolts and lock washers *(see Section 5.0)*.

HEAT EXCHANGER

The heat exchanger core is mounted inside of the water expansion tank and is sealed at the inlet and outlet ends to prevent the engine coolant from mixing with the raw cooling water.

The heat exchanger core consists of a series of cells through which the engine coolant passes and is cooled by the raw water which is forced between the cells by the raw water pump. However, the core used in the two–cylinder engine models consists of a series of flat tubes through which the raw water passes and cools the engine coolant flowing between the tubes.

To protect the heat exchanger core from the electrolytic action of the raw water, a zinc electrode is located in both the heat exchanger inlet tube and the raw water pump inlet elbow (the two–cylinder engines use only one electrode—at the raw water pump).

That portion of the tank located above the heat exchanger provides a means of filling the engine coolant system as well as space for expansion of the coolant as the temperature rises. An overflow pipe near the top of the water tank vents the tank to the atmosphere.

The length of time a heat exchanger will function satisfactorily before cleaning will be governed largely by the kind of cooling liquid used in the engine and the kind of raw water used.

- A properly inhibited antifreeze solution should be used year–round for freeze and boilover protection (refer to Section 13.3).

Enough coolant should be maintained in the engine to fill the cylinder block and head and to partially fill the water tank. Allow air space above the coolant in the tank for the increase in volume as the temperature of the coolant rises.

Whenever the heat exchanger fails to cool the engine properly, and the raw water pump is circulating a normal amount of cooling water around the heat exchanger core, the core should be examined for foreign deposits.

- **CAUTION: Use extreme care when removing a coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.**

Clean Heat Exchanger Core

When foreign deposits accumulate in the heat exchanger to the extent that cooling efficiency is impaired, remove the heat exchanger core and clean it as follows:

Immerse the heat exchanger core in a scale solvent consisting of one–third muriatic acid and two–thirds water to which one–half pound of oxalic acid has been added to each two and one–half gallons of solution. Remove the core when foaming and bubbling stops. This usually takes from thirty to sixty seconds. Flush the core thoroughly with clean hot water under pressure.

To prevent drying and hardening of accumulated foreign substances, the heat exchanger core must be cleaned as soon as possible after removing it from service.

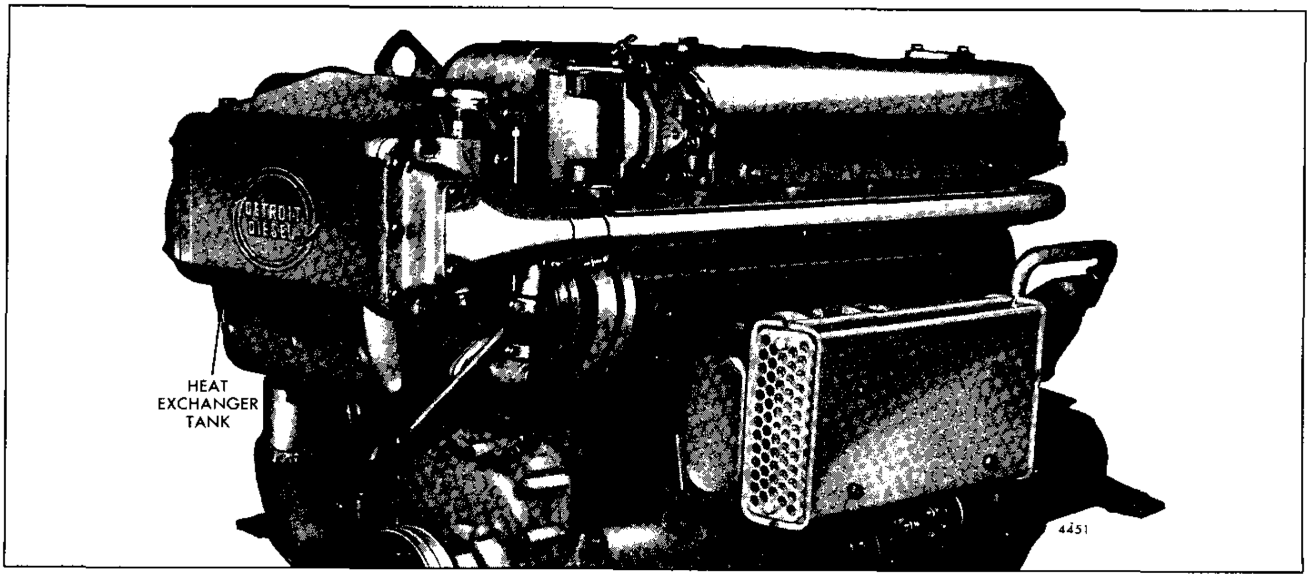


Fig. 1 – Typical Heat Exchanger Mounting In–Line Engine

• Inspect Zinc Electrodes

Remove the zinc electrodes from the inlet side of the raw water pump and the heat exchanger. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Remove Heat Exchanger Core

Remove the heat exchanger core for cleaning and inspection as follows:

1. Drain the engine coolant and raw water system.

   • **CAUTION: To avoid being burned by the hot liquid, allow the engine to cool before draining the coolant.**

2. Remove the heat exchanger core from the two–cylinder engine as follows:

   a. Remove the bolts holding the inlet and outlet covers to the expansion tank and raise the inlet tube away from the tank.

   b. Remove the seal rings from the covers.

   c. Withdraw the heat exchanger core and gasket from the tank.

3. Remove the heat exchanger core from 3, 4, 6, and 8 cylinder engines as follows:

   a. Remove four bolts that hold the inlet tube to the inlet cover. Lower the inlet tube and remove the gasket from the inlet tube flange.

   b. Remove the bolts that hold the inlet cover and heat exchanger core to the tank.

   c. Remove the bolts that hold the outlet elbow to the outlet cover. Lower the outlet elbow and remove the gasket from the flange of the elbow.

   d. Remove the bolts that secure the outlet cover to the tank.

   e. Remove the outlet cover, together with the seals and the seal gland, from the tank.

   f. Withdraw the heat exchanger core and gaskets from the tank.

Install Heat Exchanger Core

After the heat exchanger core has been cleaned and inspected, install it by reversing the sequence of operations given for removal, using new gaskets and seals.

> **NOTICE:** To minimize electrolytic action of the raw water, brass pipe plugs are used in the raw water system components wherever pipe plugs are required. Replace any steel plugs that may be found on earlier units with brass plugs.

> **NOTICE:** When installing the heat exchanger core in a two–cylinder engine, the flat sides of the tubes *MUST BE* in a vertical position to permit uninterrupted flow of engine coolant between the tubes.

Refill the engine coolant fresh and raw water systems. The cooling system must be vented when filling (see Section 5).

Prime the raw water pump, if necessary, then start the engine and check for leaks.

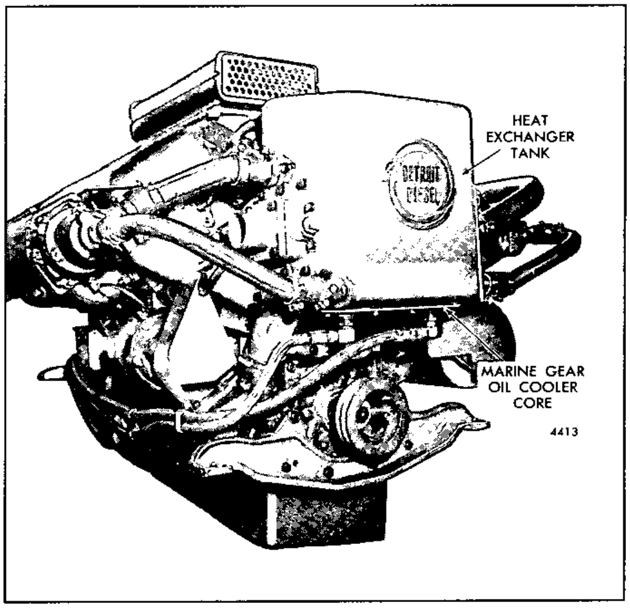


Fig. 2 – Typical Heat Exchanger Mounting V–Type Engine

RAW WATER PUMP (Jabsco)

Raw water for lowering the temperature of the engine coolant is circulated through the heat exchanger by a positive displacement pump (Figs. 1 and 2). The pump is attached to an adaptor which is, in turn, bolted to the flywheel housing. The pump is driven by a gear which meshes with the accessory drive plate mounted on the camshaft gear.

The pump drive shaft is supported by a pre–lubricated, shielded double–row ball bearing. An oil seal prevents oil leakage from the bearing compartment and a rotary type seal prevents water leakage along the shaft.

The current face–type water seal used in In–line engine pumps rides on its own mating surface. The former lip type seal rides on the shaft (Fig. 1).

An impeller splined to the end of the drive shaft is self–lubricated by the water pumped and should not be run dry longer than normally required for the pump to prime itself.

A wear plate in the impeller compartment prevents pump housing wear. This plate may be reversed if wear on the impeller side becomes excessive.

The raw water pump has been revised with the use of a new cam and wear plate assembly to improve the pump priming capabilities. The wear plate is round and conforms with the inside contour of the housing. A slot in the periphery of the wear plate registers with a dowel pin in the end of the cam, which assures a good fit and prevents the rotation of the wear plate with the pump shaft.

The top of the former wear plate was contoured to fit under the cam to prevent its rotation with the shaft.

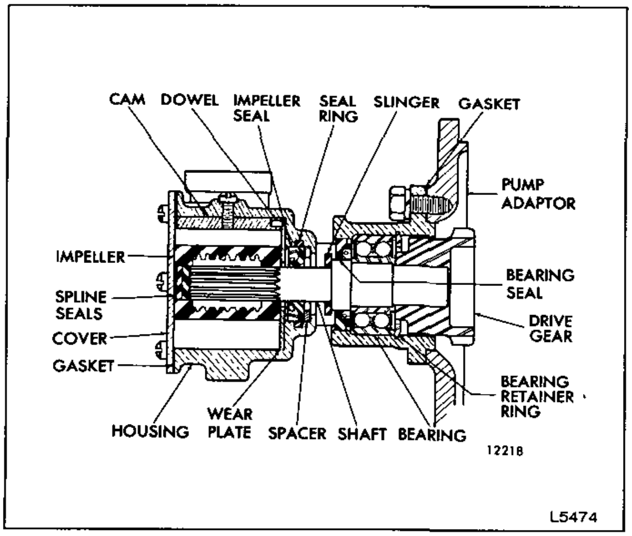


Fig. 1 – Raw Water Pump Used on In-line Engine

The current cam and wear plate assembly is interchangeable with the former cam and wear plate and only the current cam and wear plate assembly is serviced.

Operation

The pump can be operated in a clockwise or counterclockwise direction. Raw water is drawn into the pump through the inlet opening and discharged through the outlet opening. Both openings are located on the top of the pump housing.

- **NOTICE:** Always prime the raw water pump before starting the engine. Since water acts as a lubricant for the impeller, failure to prime the pump (or at least wet the impeller vanes to induce a self–priming suction) can result in severe impeller damage when the engine is started. Insufficient raw water flow into the heat exchanger caused by a damaged impeller can lead to overheating and subsequent engine damage. To prime the pump: a) remove the pipe plug from the water inlet elbow: b) pour in at least a pint of water: c) replace the plug.

•Lubrication

The shielded type double–row ball bearing is filled with lubricant when assembled. No further lubrication is required.

Replace Pump Seal

The impeller, cam and wear plate assembly and water seal assembly (Fig. 3) may be serviced without removing the pump from the engine as outlined below:

1. Remove the cover and gasket (Figs. 1 and 2).

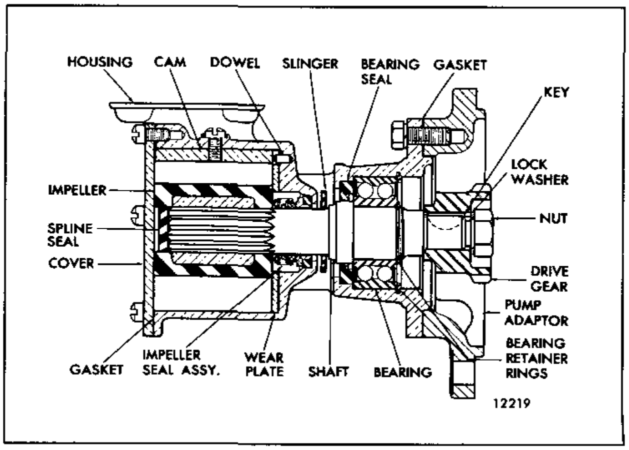


Fig. 2 – Raw Water Pump Used on V–Type Engine

2. Note the position of the impeller blades to aid in the reassembly. Then grasp a blade on each side of the impeller with pliers and pull the impeller off of the shaft.

   The neoprene spline seal(s) can be removed from the impeller by pushing a screwdriver through the impeller from the open end. If the impeller is reuseable, exercise care to prevent damage to the splined surfaces.

3. Remove the cam retaining screw and withdraw the cam and wear plate assembly.

4. Remove the seal assembly (Fig. 3) from the pump used on the V–type engine by inserting two wires with hooked ends between the pump housing and the seal, with the hooks over the edge of the carbon seal. Remove the seal seat and gasket in the same way.

   The seal may be removed from the pump used on the In–line engine by drilling two holes in the seal case and placing metal screws in the holes so that they may be grasped and pulled with pliers. Then, remove the rubber seal ring from the groove in the former pump housing.

5. Clean and inspect the impeller, cam and wear plate assembly and water seal. The impeller must have a good bond between the neoprene and the metal. If the impeller blades are damaged, worn or have taken a permanent set, replace the impeller. Reverse the wear plate if it is worn excessively and remove any burrs. Replace the seal, if necessary.

6. Install the seal assembly in the pump used on the V–type engine as follows:

   a. If the seal seat and gasket were removed, place the gasket and seal seat over the shaft and press them into position in the seal cavity.

   b. Place the seal ring securely in the ferrule and, with the carbon seal and washer correctly positioned against the ferrule, slide the ferrule over the shaft and against the seal seat. Use care to ensure the seal ring is contained within the ferrule so that it grips the shaft.

   c. Install the flat washer and then the marcel washer.

   Install the face–type water seal and spacer over the shaft in the impeller end of the current pump housing. Push the seal against the spacer. The seal is a snug fit on the shaft.

   A lip type seal may be installed in the former pump used on the In–line engine by placing the rubber seal ring in the groove, starting the seal with the lip facing the impeller cavity over the shaft and tapping it into place against the seal spacer.

7. Install the cam and wear plate assembly. The former wear plate was installed separately with the contoured surface fitting under the cam. The current wear plate is round and is doweled to the cam. The wear plate *must* be installed with the cam in the pump housing as an assembly.

8. Apply a non–hardening sealant to the cam retaining screw and the hole in the pump body to prevent any leakage. Then, hold the cam with the tapped hole aligned and secure it with the screw.

9. Compress the impeller blades to clear the offset cam and press the impeller on the splined shaft.

10. Install the neoprene spline seal(s) in the bore of the impeller.

11. Turn the impeller several revolutions in the normal direction of rotation to position the blades.

12. Affix a new gasket and install the pump cover.

Remove Pump from Engine

If complete disassembly or replacement of the pump is necessary, it may be removed from the engine as follows:

1. Drain the raw water system.

2. Remove the water inlet and outlet elbows and discard the gaskets.

3. Remove the bolts that secure the pump adaptor to the flywheel housing.

4. Tap the edge of the adaptor with a plastic hammer to loosen the pump.

5. Pull the pump straight out from the flywheel housing so the drive gear will disengage the coupling.

6. Cover the pump opening in the flywheel housing with a clean cloth to prevent the entrance of foreign matter.

Disassemble Pump

Follow the procedure outlined under *Replace Pump Seal* for the removal of the impeller, cam and wear plate assembly and water seal assembly and then proceed as follows:

1. Mark the pump housing and adaptor to aid in reassembly. Then remove the bolts and separate the housing and adaptor.

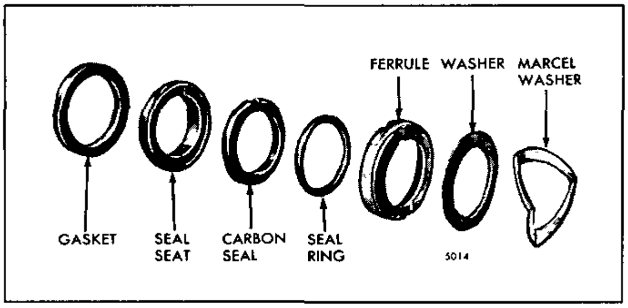


Fig. 3 - V–Type Engine Impeller Seal Detail

2. Clamp the V–type engine pump drive gear and housing assembly in a vise with soft jaws and remove the drive gear retaining nut. Take out the Woodruff key and remove the assembly from the vise.

   Use puller J 24420 to remove the drive gear from the In–line engine pump.

3. Remove the bearing retainer ring from the groove in the housing.

4. Support the pump body in an arbor press with the splined end of the pump drive shaft under the ram of the press. Place a brass rod on the end of the shaft. Then press the shaft and bearing assembly out of the pump housing.

5. Remove the slinger from the opening in the top of the pump housing, then remove the bearing seal from the inside of the housing. Remove the bearing retainer ring from the groove in the pump shaft on the V–type engine pump.

6. Place a suitable sleeve over the shoulder on the pump drive shaft and against the inner race of the bearing. Place the sleeve, shaft and bearing assembly on the bed of an arbor press with the threaded end of the shaft up. Hold a brass rod on the end of the shaft and press the bearing off of the shaft.

Inspect Pump Parts

After disassembling the pump, clean all of the parts thoroughly, except the bearing.

- **NOTICE:** The shielded bearing must not be washed; dirt may be washed in and the cleaning fluid may not be entirely removed from the bearing.

Wipe the bearing clean on the outside and then inspect it. Hold the inner race and revolve the outer race slowly to detect possible wear or rough spots. Replace the bearing if it is worn or does not roll freely.

Examine the components of the seal assembly and discard any parts that have been worn or otherwise damaged.

On the V–type engine pump, inspect the carbon seal components. Replace worn or damaged parts, as necessary.

Check the pump drive shaft seal contact surfaces for wear. Remove any scratches with crocus cloth wet with fuel oil.

Refer to Item 5 under *Replace Pump Seal* for the inspection of the remaining parts.

Assemble Pump

Use new parts where necessary and assemble the pump as follows:

1. Lubricate the inside diameter of the drive shaft bearing with engine oil and start it, numbered side up, straight on the drive gear end of the shaft. Place a suitable sleeve over the shaft and against the inner race of the bearing. Support the sleeve, bearing and shaft on the bed of an arbor press and press the shaft into the bearing until the shoulder on the shaft is tight against the bearing inner race. On the V–type engine pump, install the bearing retainer ring in the groove on the shaft.

2. Coat the lip of the seal lightly with grease and place it in position in the pump housing with the lip of the seal facing away from the bearing cavity.

3. Start the splined end of the drive shaft into and just through the inner bearing seal in the center of the pump housing from the drive flange end. Place the slinger in the opening in the top of the housing and over the end of the shaft. Carefully push the shaft straight into the housing until the bearing starts into the bearing bore. Use care to prevent damage to the slinger.

4. Support the impeller end of the housing on the bed of an arbor press. Place a suitable sleeve on the outer race of the bearing and under the ram of the press and press the bearing straight into the bearing cavity in the pump housing.

5. Install the bearing retainer ring in the groove in the housing.

6. Lubricate the bore of the drive gear and start it on the shaft. A Woodruff key is used with the shaft in the V–type engine pump.

7. Support the in–line engine pump housing and drive shaft assembly on the bed of an arbor press with the splined end of the drive shaft resting on a steel block and the drive gear under the ram of the press. Press the gear on the shaft until it is tight against the shoulder.

   Clamp the V–type engine pump drive gear and housing assembly in a vise with soft jaws and install the gear retaining nut and lock washer. Tighten the nut to 25–30 lb–ft (27–41 N·m) torque. Then remove the pump assembly from the vise.

- **NOTICE:** Exceeding the specified torque may cause pump drive shaft damage.

8. Place a new gasket on the pump adaptor, align the match marks and install the pump housing on the adaptor with the bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

9. Follow the procedure outlined under *Replace Pump Seal* for the installation of the impeller, cam and wear plate assembly and water seal assembly.

Install Pump

The raw water pump may be installed on the engine by reversing the procedure for removal.

The pump end cover is marked to indicate the outlet port for a RH rotation and the outlet port for a LH rotation pump installation. These markings are an aid to prevent any difficulty with regard to water flow direction.

After the pump has been installed, prime it before starting the engine.

Drain Pump in Freezing Temperatures

The raw water pump is not provided with a drain valve. If freezing temperatures are anticipated and the engine is not going to be operated or the engine is being placed in storage, it is recommended that the raw water pump impeller housing be drained in addition to draining the engine cooling system.

Drain the raw water pump impeller housing by carefully pulling the pump cover away from the housing after loosening the screws. If the gasket is damaged, the cover will have to be removed and the gasket replaced.

After the pump has been drained, replace the cover and tighten the screws.

COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a replaceable canister type element (Fig. 1), a spin–on type element (Fig. 2) or a clamp–on type element (Fig. 3).

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid–free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system (refer to Section 13.3). The other components of the element perform the function of cleaning and preparing the cooling passages while the corrosion inhibitors protect them.

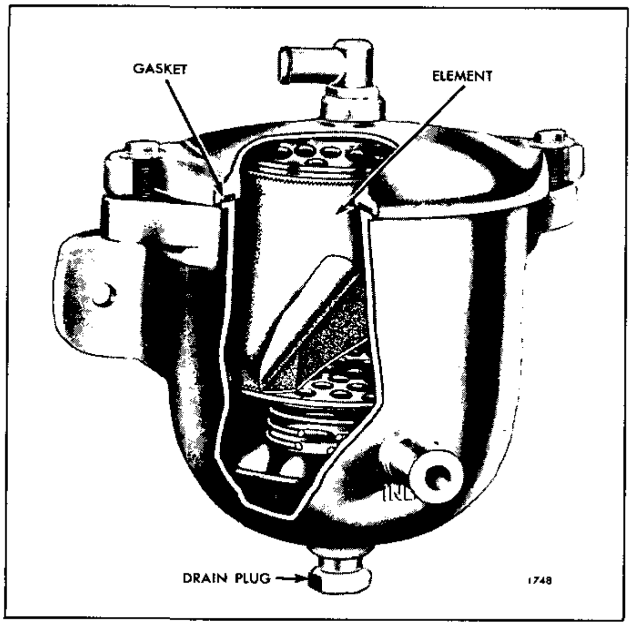


Fig. 1 – Coolant Filter and Conditioner (Canister Type)

Filter Installation

If a coolant filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to installation of the filter.

Filter Maintenance

Replace the chemically activated element, following the manufacturer's recommended change periods (refer to Section 15.1). The lower corrosion resistor plate (if used) must be buffed each time (discard the plate, if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of approximately 200 hours or 6,000 miles, or less, to clean–up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these initial change intervals.

Make–up water up to approximately 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

> **NOTICE:** Sea water must never be used for make–up water in a marine engine, except under emergency conditions. If it is necessary to use sea water, the cooling system must be completely drained and flushed with fresh water upon reaching port. The filter element must be changed. Filters with resistor plates must be inspected for pitting. *Presence of salt in the coolant results in rapid pitting of the resistor plates.*

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and reused. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

Service

The coolant filter may be grounded at the option of the user.

The current coolant filter includes a non–chromate type element. This element can be used in place of either of the former filter elements (permanent type antifreeze or plain water type) and thus provides year around cooling system protection. The current and the former filter elements are completely interchangeable in the former filter can (refer to Section 13.3).

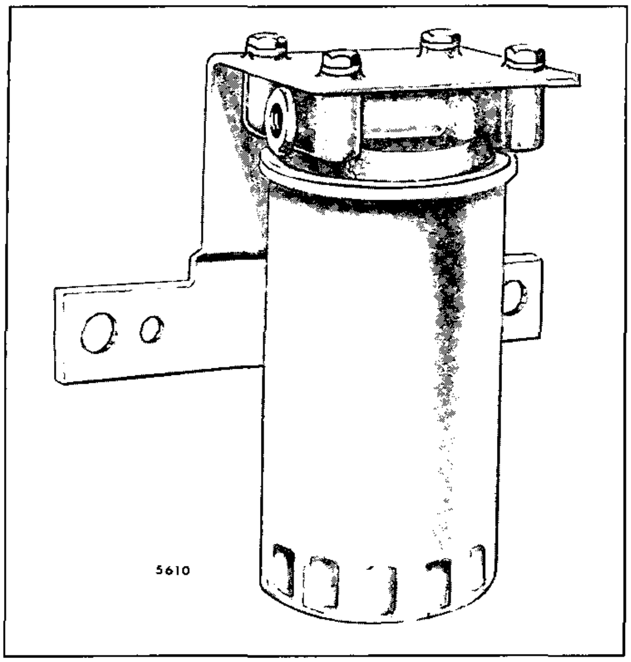


Fig 2. – Coolant Filter and Conditioner (Spin–On Type)

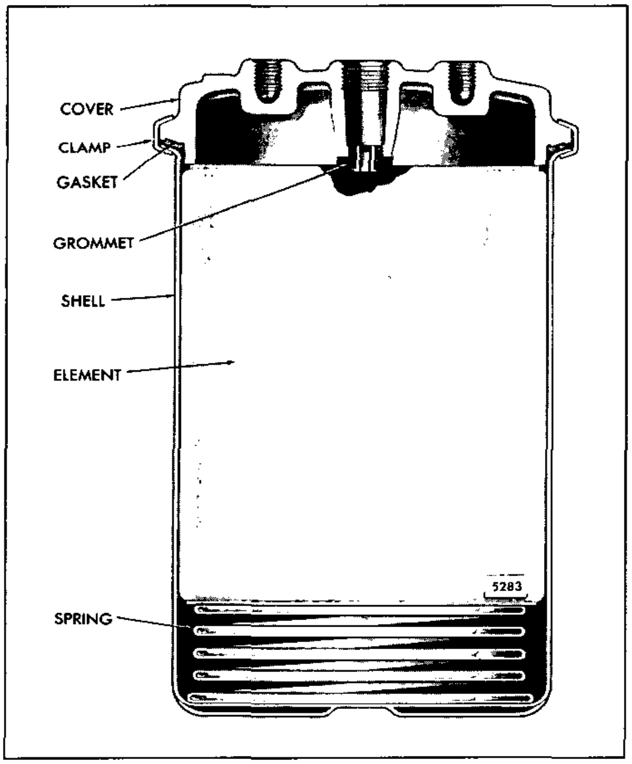


Fig. 3 – Coolant Filter and Conditioner (Clamp–On Type)

Replace the element and service the filter and conditioner as follows:

1. Close the filter inlet and outlet shutoff valves. If shutoff valves are not provided, vise grip pliers can be used to clamp each hose closed during the filter change. Use caution to avoid damaging the hoses with the vise grip pliers.

2. Remove and replace the element as follows:

Canister Type Element – Fig. 1:

a. Remove the drain plug in the bottom of the filter body and let drain.

b. Remove the filter cover–to–filter body bolts.

c. Remove and discard the element.

d. Remove and discard the corrosion resistor plates.

e. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

f. Replace the drain plug in the bottom of the filter.

g. Insert the new element.

h. Use a new filter cover gasket and install the filter cover and tighten the bolts evenly.

Spin–On Type Element – Fig. 2:

a. Remove and discard the element.

b. Clean the gasket seal on the filter cover.

c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

d. Apply clean engine oil to the filter element gasket and install the new element. A 2/3 turn after gasket contact assures a positive leakproof seal.

Clamp–On Type Element – Fig. 3:

a. Remove the retaining clamp.

b. Remove and discard the element.

c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

d. Insert the new element.

e. Secure the filter body in place with the clamp.

3. Open the inlet and outlet lines by opening the shutoff valves or removing the vise grip plier clamps.

4. Operate the engine and check for leaks. The top of the filter and the outlet line should feel warm to the touch with the rise in coolant temperature. If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system and reconnect the line. Use caution to minimize coolant loss.

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

FAN HUB SPACER

The new fan hub spacers are similar to the former spacers except for the flange pilot radius and the width of the spacers (Fig. 1). The flange on the spacer serves as a pilot for the fan, as well as a pilot for the second spacer when two or more spacers are used together.

The former and new spacers are interchangeable on a former fan pulley hub assembly and only the new spacers are serviced.

The former .800" thick spacer must not be used with the current shaft type fan pulley hub assemblies, unless it is reworked (see Service Note).

NOTICE: Use of the former thick spacer will crush the fan hub cap causing the drive to bind.

The former .800" thick spacer can be reworked into the new .800" thick spacer by removing material at the radius (Fig. 1). A reworked spacer should be mated with the fan hub assembly. If a former thin spacer (.500" thick) is used in conjunction with the reworked thick spacer, it should be positioned against the fan.

The .500" thick spacer cannot be reworked into the new .560" thick spacer.

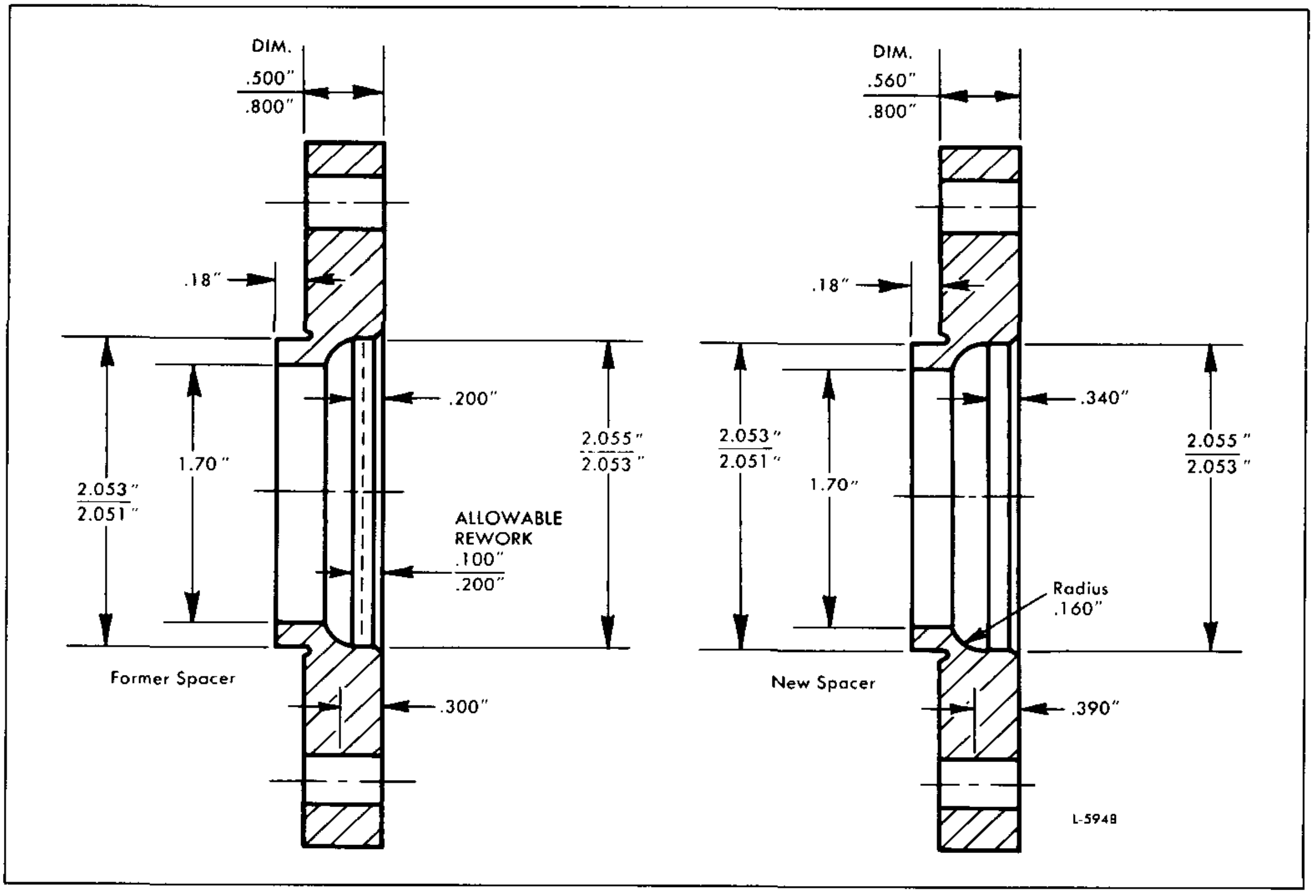


Fig. 1 – Former and New Spacers

FAN HUB GREASE FITTING

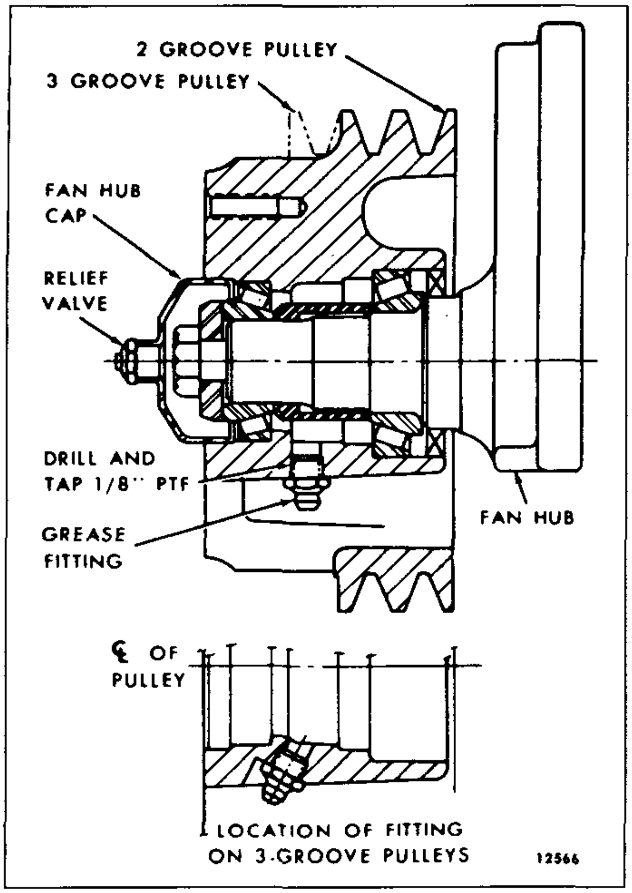


Fig. 2 – Location of Fan Hub Grease Fitting and Relief Valve

A grease fitting may be added to former fan hub assemblies used on vehicle engines to permit periodic lubrication of the bearings.

Rework the fan hub as follows:

1. Refer to Section 5.4 and disassemble the fan hub assembly and clean the parts throughly.
2. Drill and tap the fan hub, at the location shown in Fig. 2, to accept a 1/8" PTF x 11/16" threaded lubricator fitting. Clean the hub to remove any metal chips.
3. Refer to Section 5.4 and reassemble the fan hub. Discard the former grease retainer as it is not required when a grease fitting is used.
4. Install a *new* fan hub cap which is threaded for a relief valve (Fig. 2).
5. Install a grease fitting in the fan hub and a relief valve in the fan hub cap.

Refer to Section 15.1 for the maintenance schedule.

DRAINING JABSCO RAW WATER PUMP

Although all engine units are provided with draincocks for the purpose of draining the cooling system, a small amount of coolant may remain in the impeller housing of a Jabsco pump.

Under normal circumstances, there would be no need in completely draining the impeller housing of a raw water pump, therefore, no drain plug has been incorporated at this location. However, certain models employ a raw water pump in conjunction with a fresh water cooling system.

In the event the engine is to be stored in below freezing temperatures, it is suggested that, in addition to draining the cooling system of the engine unit, the impeller housing of the Jabsco pump (if so equipped) be completely drained. This may easily be accomplished by loosening the five fillister head screws which attach the end cover to the pump housing, at the impeller end of the pump, then pulling the end cover away from the pump body, while being careful to avoid damage to the gasket. The screws need only be loosened *sufficiently to allow complete draining of the impeller* housing, then retightened.

RAW WATER PUMP IMPELLERS

The Jabsco raw water pump is equipped with synthetic rubber impellers. Since the synthetic rubber begins to lose its elasticity at low temperatures, impellers made of natural rubber may be installed when it is necessary to pump raw water that has a temperature below 40°F (4°C). However, the standard impellers must be used when the pump operates in warmer water.

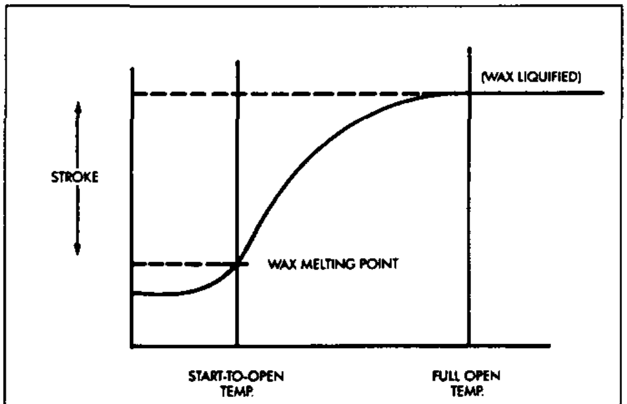
New service impellers of natural rubber are identified by a stripe of green paint.

•THERMOSTAT FUNCTION TESTING

Thermostat print specifications normally call for three specific operating conditions: namely, start–to–open temperature, full–open temperature, and full–open dimension. The most important of these is the *start–to–open* temperature. This is the temperature at which the motor mechanism (wax compound) experiences a change from a solid to a liquid, expanding and opening the thermostat to allow coolant flow. At full–open temperature, the liquid wax is fully expanded and the full–open dimension is reached, ensuring proper coolant flow to the radiator. The start–to–open temperature is normally stamped or printed on the thermostat.

A definite relationship exists between the start–to–open temperature and operating stroke (full–open travel) of the thermostat. This relationship may be seen in the illustration at right. The normal tolerance for the start–to–open temperature is +2°F or -3°F (+1.11°C or -1.67°C).

To ensure that sufficiant coolant flows through the radiator to control engine temperature, the start–to–open temperature and the full–open dimension of the thermostat should be checked. Thermostats may be tested on the simple fixture shown (Fig. 5). This fixture can be made from readily available materials.



L-6562

Materials

1 Stainless steel or non–ferrous metal vessel approximately 8″ diameter by 6″ deep

1 2000 watt immersion–type heating element

1 Thermostatic control having a 60°F to 230°F (15.6° to 110°C) temperature range and a capillary tube sensing device

1 12″ length of 1/4″ copper tubing

1 3/8″ drain valve

1 7 1/2″ diameter piece of 12–gague galvanized sheet steel or 1/8″ aluminum (for bed plate)

1 Bulkhead fitting

1 Air control valve

1 Laboratory thermometer with a 60°F to 230°F (15.6°C to 110°C) range

1 Dial indicator having a one inch travel with a 3/8" gauge holding rod and swivel post lock screw

The thermostat test fixture consists of the test vessel with control (Fig. 4) and the test plate assembly (Fig. 3).

Making the Test Fixture

1. Drill a 1/8" hole in the side of the vessel and braze a bulkhead fitting to the vessel to accept an air control valve. Shop air will be used to agitate the water and relieve temperature stratification within the vessel.
2. Manufacture an aeration line from a 12" length of 1/4" copper tubing by drilling four equally spaced 1/8" holes in the tube and crimping or blocking one end. Attach the open end of the tube to the air valve and bend the tube to the inside contour of the vessel.
3. Install a 3/8" drain valve in the lower portion of the vessel.

A. BED PLATE
B. THERMOSTAT BORE
C. THERMOMETER HOLE
D. UPRIGHT BASE POST
E. GAUGE HOLDING ROD
F. SWIVEL POST SNUG
G. DIAL INDICATOR

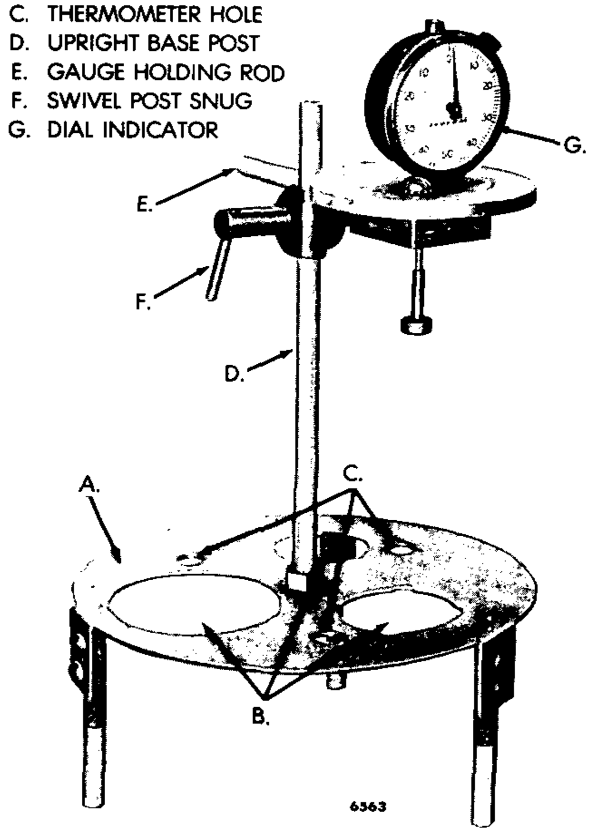


Fig. 3 – Test Plate Assembly

4. Fabricate the bed plate from 12–gauge galvanized steel or 1/8" aluminum sheet stock. The bed plate is used to suspend the thermostat at a mid–point in the vessel. This component must fit squarely in the vessel and have legs of sufficient length to ensure that stats won't contact the heating element and aeration line.

   Bore 1 9/16", 2", and 2 3/4" holes in the plate spaced 120° from each other to facilitate the installation of the variety of stats normally encountered. Drill three 7/16" holes at 60° from each thermostat mounting bore for conveniently locating a thermometer during testing.

   Install a 3/8" x 8" upright base post in the center of the plate to provide the mounting for a dial indicator.
5. Attach the dial indicator gauge to the upright center post of the plate to permit accurate thermostat travel measurement. The bed plate and dial indicator shown have components added to raise the indicator vertically above the gauge holding rod; however, the extra items are not required.

Thermostat Testing Procedure

NOTICE: This procedure will take time to do properly. Refer to Fig. 5.

Place the vessel on a level surface and lower the bed plate into position, being careful to avoid contact with the heating element.

Fully submerge the thermostat in warm water and place a laboratory thermometer in one of the 7/16" holes on the bed plate. Position the dial indicator over the thermostat, centering the contact point on the motor mechanism. Zero the dial. To ensure accurate test results, allow the thermostat to warm up to water temperature before testing. Then, turn on the heating element (if necessary) and bring water temperature to a few degrees below the start–to–open temperature of the thermostat being tested. Hold at this temperature for 2–3 minutes.

With the heating element on, adjust the air valve to sufficiently agitate the water for equal heat distribution. Bring bath temperature up to the maximum specified start–to–open temperature of the thermostat. Observe the dial indicator and note the temperature at which the needle just begins to move. This is referred to as the *start–to–open temperature.* The total indicator travel, from star–to–open to full–open is referred to as the *full open travel.*

For full–open temperature and travel, raise bath temperature a few degrees above the specified full–open temperature and hold at that temperature for 2 to 3 minutes.

To efficiently test a number of thermostats, simply add cold water to the vessel. This will reduce the water temperature to a level below the next thermostat opening temperature, thus saving time. Turn the heating element off after completing the tests.

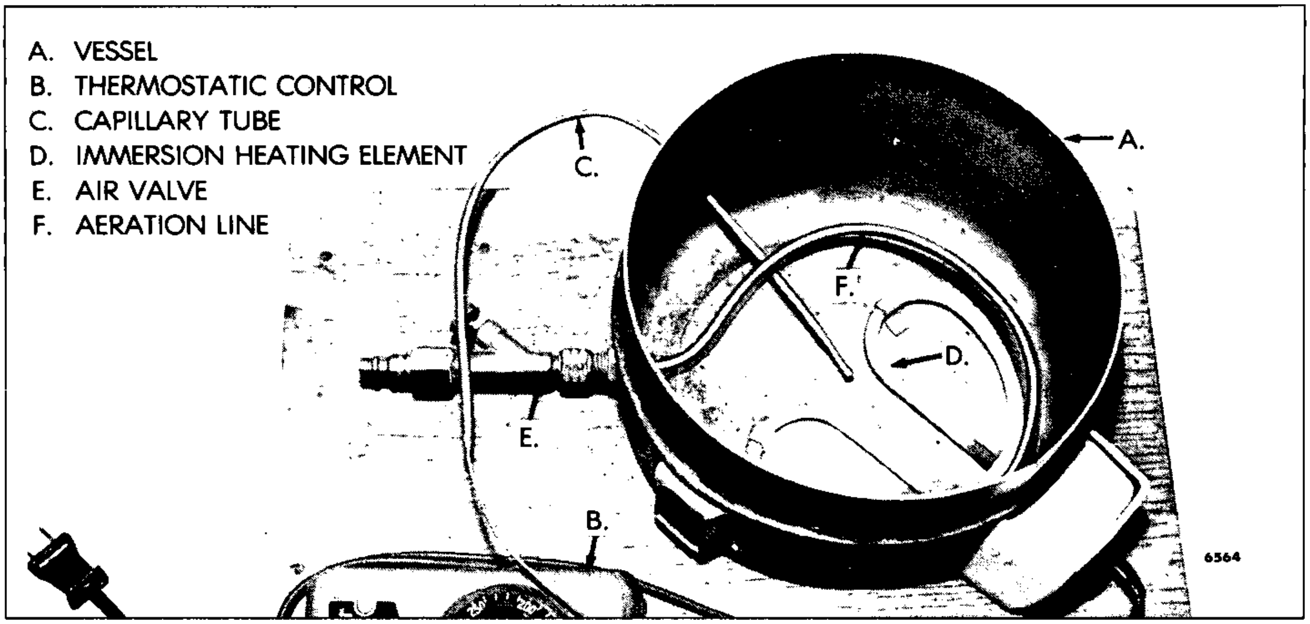


Fig. 4 – Test Vessel and Control

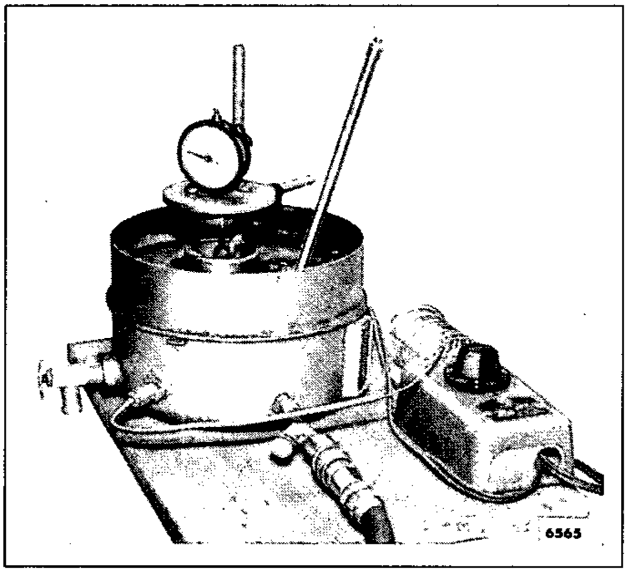


Fig. 5 – Testing a Thermostat in the Test Fixture

Conducting Cooling Tests

When conducting cooling tests on an engine, it is essential that maximum radiator/heat exchanger coolant flow be achieved. Coolant flow and, subsequently, the accuracy of cooling system test results depend to a large extent on the condition of the thermostat installation. If maximum flow does not occur, check for these causes:

1. Thermostat(s) not blocked open to correct dimension.
2. Thermostat housing seal(s) missing.
3. Thermostat housing seal(s) worn.
4. Thermostat housing cover bypass cavity sealing surface(s) not centered and/or worn.

• FIND COOLANT LEAKS WITH FLUORESCENT DYE, BLACK LIGHT

Finding the source of an engine coolant leak is often a time–consuming affair. To speed the process, a fluorescent dye such as *15174 Uranine* (or equivalent) may be added to the coolant. Under an ultraviolet "black light," the Uranine dye–treated coolant turns a highly visible, bright yellow–green color, making the leak path easy to trace.

15174 Uranine is manufactured by Chemcentral Corporation and is available through their distributor network. For further information contact:

CHEMCENTRAL CORPORATION
7050 West 71st Street
Chicago, Illinois 60638

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	260M BOLTS TORQUE N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	280M OR BETTER TORQUE N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	lb–ft	N·m
Water pump cover bolt	5/16–18	6–7	8.1–9.5
Fan hub retaining nut (6V engines)	1/2–20	35–40	47–54
Raw water pump drive gear retaining nut	5/8–18	30–35	41–47

SERVICE TOOLS

TOOL NAME	TOOL NO.
Handle, driver (1/2″ diameter)	J 7079–2
Installer, thermostat housing seal (8V–53)	J 22091
Puller	J 24420–A
Radiator cap and cooling system tester	J 24460–01
Remover and installer, water pump coupling and oil seal (8V–53)	J 1930
Water pump impeller remover set	J 22488

SECTION 6

EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

Fan and radiator–cooled engines are equipped with an air–cooled exhaust manifold. A water–cooled exhaust manifold is provided for engines incorporating a heat exchanger or keel cooling system.

The outlet flange may be located at the end or at the mid–section of the exhaust manifold, depending upon the installation requirements. A flexible exhaust connection or a muffler may be attached to the outlet flange.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

EXHAUST MANIFOLD (AIR-COOLED)

Two types of exhaust manifolds are used. One type has an outlet to accommodate a square exhaust outlet flange (Fig. 1) and the other has a circular outlet which is connected to the exhaust pipe with a Marmon-type clamp (Fig. 2). Current manifolds, flanges (square) and flange gaskets have SAE standard dimensions.

On engines equipped with a mechanical automatic shutdown system, the exhaust manifold is provided with two 5/16"-18 tapped bolt holes and a 7/8" drilled hole to permit installation of the temperature shutdown valve adaptor and plug assembly.

Remove Exhaust Manifold

1. Allow the engine to cool. Then disconnect the exhaust pipe or muffler from the exhaust manifold flange.
2. If the engine is equipped with a mechanical automatic shutdown system, remove the two bolts and lock washers and withdraw the shutdown valve adaptor and plug assembly from the exhaust manifold.
3. Loosen, but do not remove, one of the center exhaust manifold nuts. Remove the other nuts and washers.
4. Support the manifold and remove the center nut and washer.
5. Remove the manifold and gasket from the cylinder head.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Clean the manifold and check for cracks, especially in the holding lug areas.

Clean all traces of gasket material from the cylinder head.

Replace broken or damaged exhaust manifold studs. Apply sealant to the threads and drive new studs to 25–40 lb-ft (34–54 N·m) torque (1.40" to 1.50" height).

Install Exhaust Manifold

1. Place a new gasket over the studs and against the cylinder head.
2. Position the exhaust manifold over the studs and hold it against the cylinder head.
3. Install the washers and nuts on the studs. If beveled *(dished) washers are used, position them so that the* crown side faces the nut. On some engines, crabs are used in place of washers at the end positions (Fig. 2). Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30–35 lb-ft (41–47 N·m) torque.

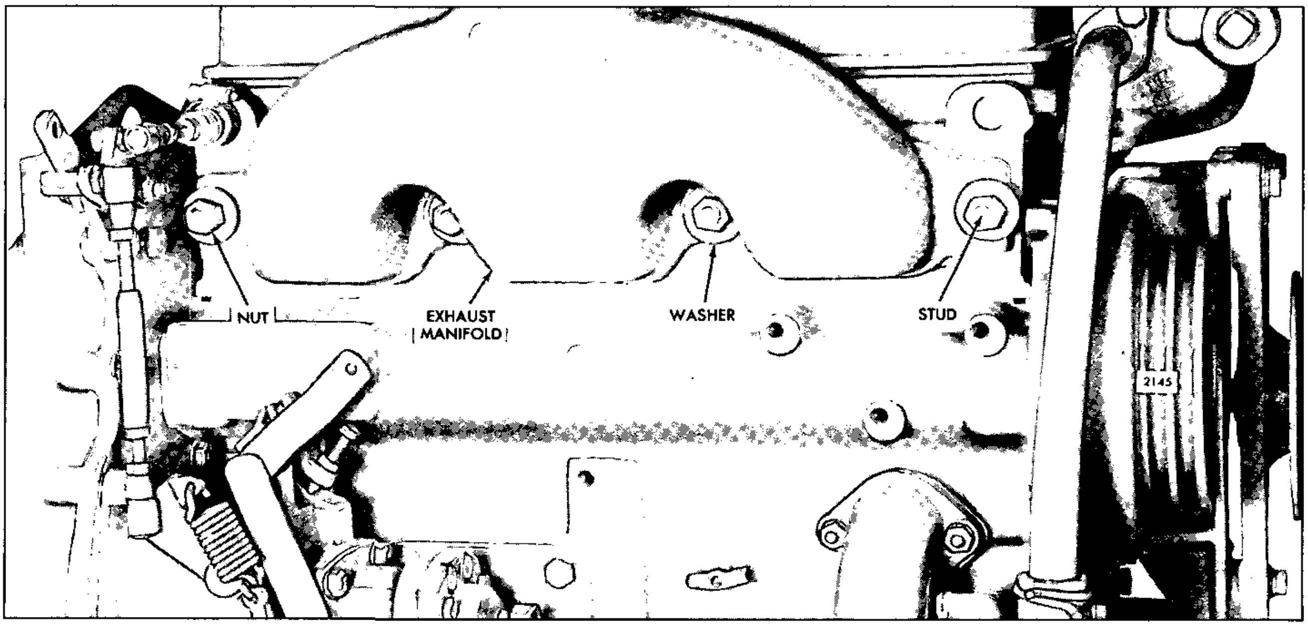


Fig. 1 – Typical Air-Cooled Exhaust Manifold (Square Flange) Mounting

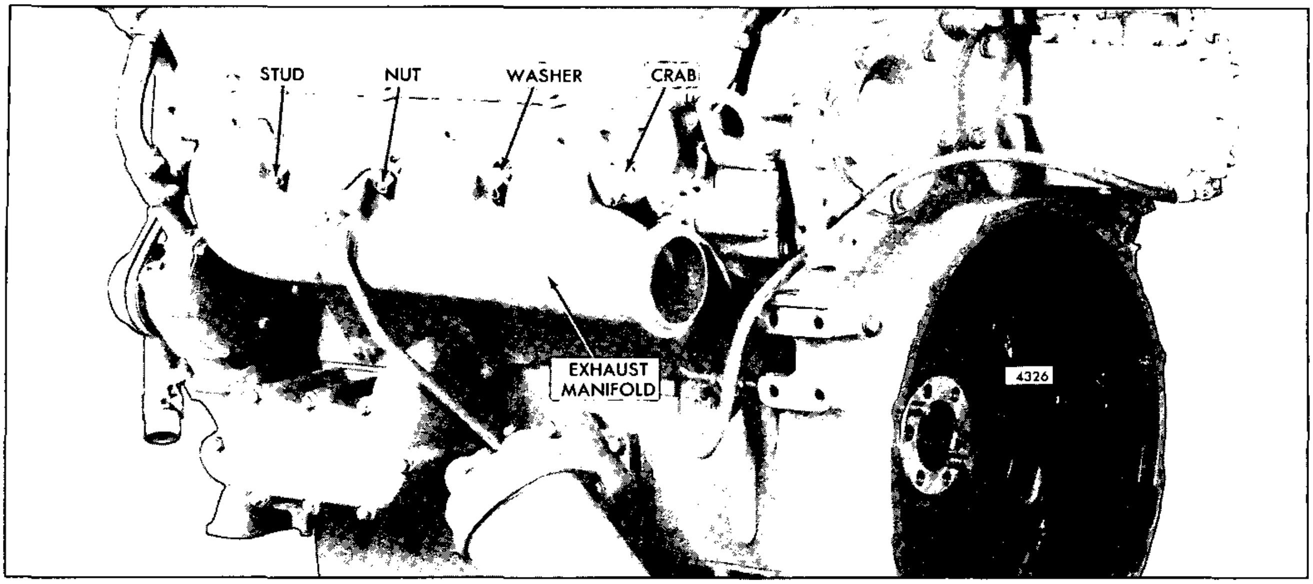


Fig. 2 – Exhaust Manifold with Marmon Flange

4. *If the engine is equipped with a mechanical automatic* shutdown assembly, install the shutdown valve adaptor and plug assembly in the exhaust manifold and secure it with two bolts and lock washers.

5. Connect the exhaust pipe or muffler to the exhaust manifold flange.

NOTICE: *To avoid turbocharger damage, do* not allow exhaust piping to impose excessive loads on the turbocharger.

6. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

EXHAUST MANIFOLD (WATER-COOLED)

A water jacket surrounds the exhaust chamber in the cast iron water–cooled exhaust manifold illustrated in Fig. 1. The engine coolant flows from the rear of the cylinder head through the water jacket around the exhaust manifold and through the thermostat housing and the water bypass tube to the water tank.

Remove Exhaust Manifold

1. Allow the engine to cool. Then remove the water tank filler cap and open the vent valve at the front end of the exhaust manifold.

- **CAUTION: Use extreme care when removing a coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.**

2. Drain the cooling system.
3. Disconnect the exhaust pipe from the exhaust manifold flange.
4. Loosen the hose clamps and slide the hose back on the water inlet connector attached to the rear end of the cylinder head. On some engines, the connector is a formed hose which can be removed.
5. Disconnect the water tank vent tube, if used, at the exhaust manifold.
6. Loosen the hose clamps and slide the hoses back on the water bypass tube and the heat exchanger water inlet tube or the thermostat housing.
7. If a water filter is used, disconnect the filter hose to the exhaust manifold.
8. Loosen the hose clamps at each end of the raw water pump outlet intermediate tube and slide the hose back on the tube at the curved end, then slide the tube out of the hose at the heat exchanger end.
9. Support the manifold and remove the nuts and washers which secure it to the cylinder head.
10. Remove the manifold and manifold gasket.
11. If necessary, remove the exhaust manifold flange at the rear of the manifold and the water outlet flange at the front.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold.

Clean all traces of gasket material from the cylinder head.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. Apply sealant to the threads and drive new studs in to a height of 1.40" to 1.50" or to 25–40 lb-ft (34–54 N·m) torque.

Install Exhaust Manifold

1. If removed, install the exhaust flange and water outlet flange on the exhaust manifold.
2. Place a new gasket over the studs and against the cylinder head.

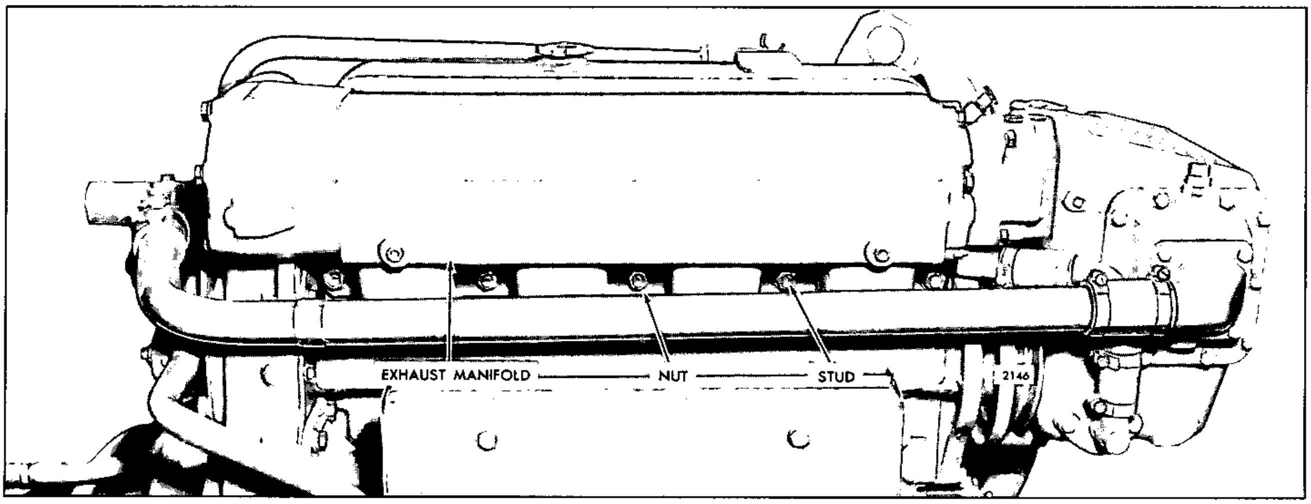
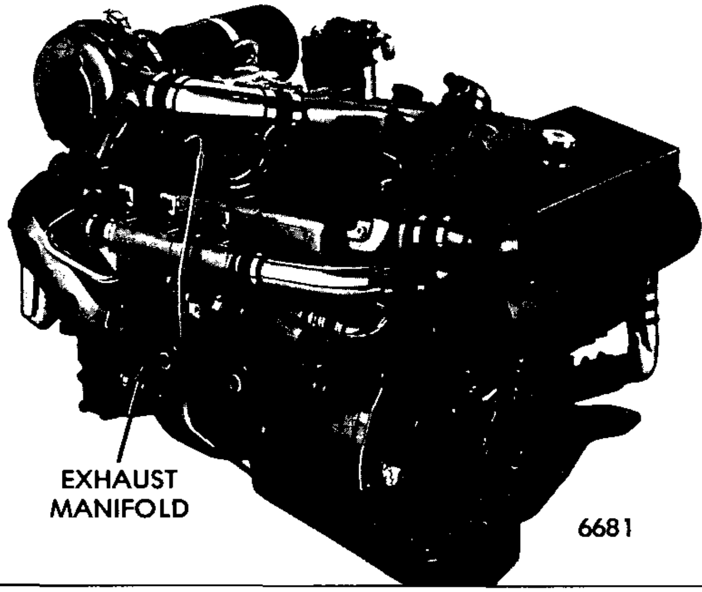


Fig. 1 – Typical Water–Cooled Exhaust Manifold Mounting (In–Line Engine)



• Fig. 2 – Typical Water-Cooled Exhaust Manifold Mounting (6V Engine)

3. Position the exhaust manifold over the studs and hold it against the cylinder head. Be sure the locating pads on the exhaust manifold rest on the cylinder block locating pads.

4. Install the washers and nuts on the studs. Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30–35 lb–ft (41–47 N·m) torque.

5. Slide the hoses in place on the water bypass tube and the heat exchanger water inlet tube or the thermostat housing and tighten the hose clamps.

6. Install the formed hose or slide the hose in place on the water inlet connector attached to the rear of the cylinder head. Tighten the hose clamps.

7. If used, connect the water tank vent tube to the exhaust manifold.

8. If the engine is equipped with a water filter, connect the filter hose to the exhaust manifold.

9. Install the raw water pump outlet intermediate tube, slide the hoses in place and tighten the hose clamps.

10. Connect the exhaust pipe to the exhaust manifold flange.

NOTICE: To avoid turbocharger damage, do not allow exhaust piping to impose excessive loads on the turbocharger.

11. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

12. Close the drain valves and fill the cooling system.

13. Close the vent valve at the front end of the exhaust manifold and install the water tank filler cap.

14. Start the engine and check for leaks in the cooling system.

SECTION 7

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

CONTENTS

ELECTRICAL SYSTEM

A typical engine electrical system generally consists of the starting motor(s), a battery–charging alternator, storage batteries and the necessary wiring. Additional equipment such as an engine protective system may also be included.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco–Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC–Delco service outlets, or from the Technical Literature Section, Delco–Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Corporation. For electrical equipment manufactured by Delco–Remy Division, repair service and parts are available through AC–Delco branches and repair stations.

- **CAUTION: To avoid possible personal injury and/or engine damage from accidental engine startup, always disconnect the battery before servicing the electrical system.**

BATTERY–CHARGING ALTERNATOR

The battery–charging circuit consists of an alternator, battery (Section 7.2), and the wiring. The battery–charging alternator (Figs. 1 and 2) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

- All In–line 53 engines and most 6V–53 engines use hinge–mounted (belt–driven) alternators. Certain 6V–53 models use flange–mounted (beltless) alternators.

• ALTERNATOR PRECAUTIONS

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running, or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery will result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

In marine applications which have two sets of batteries, switching from one set of batteries to the other while the engine is running will momentarily disconnect the batteries and result in damage to the alternator diodes.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output.

Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed.

HINGE–MOUNTED ALTERNATOR (BELT–DRIVEN)

The hinge–mounted alternating current self–rectifying alternator, (Figs. 1 and 2) is belt–driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A.C. voltage to provide D.C. voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier. The alternator is also available in various sizes and types, depending upon the specific application.

The SI series alternators have replaced the DN series alternator. With the new alternators, the need for a separately mounted voltage regulator is eliminated.

The 32 volt, 50 ampere 25SI alternator has been replaced by the 30SI alternator, rated at 60 amperes, for marine applications. When installing the 30SI alternator, a wire running from the alternator to the battery (insulated ground vs negative ground) must be installed.

The access hole permitting the external adjustment of the voltage regulator has been eliminated on current alternators. To adjust the voltage setting on the current alternators, remove the rectifier end plate. The voltage regulator adjustment is located on the voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

The proper selection of an alternator which will meet the needs of the battery–charging circuit on the particular engine is mandatory. This, together with adherence to the recommended maintenance procedures will reduce alternator troubles to a minimum. Since most alternators adhere to the same basic design, the maintenance, removal and installation procedures for all are similar.

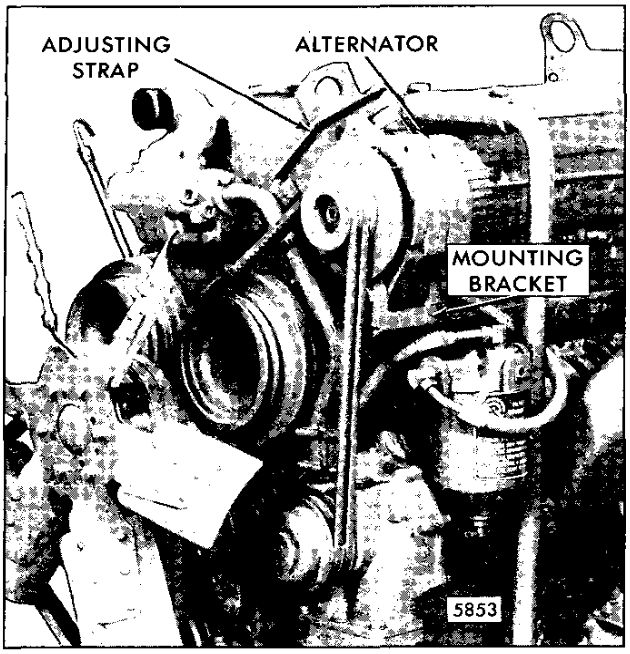


Fig. 1 – Typical Hinge–Mounted Alternator (In–line 53)

Alternator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the alternator drive.

2. When installing or adjusting the drive belt, be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

3. Alternator bearings are permanently lubricated. There are no external oiler fittings.

Remove Alternator

1. Disconnect the cables at the battery supply.

   - **NOTICE:** To avoid alternator damage when removing battery connections, disconnect the negative (–) terminal first. When reinstalling connections, reconnect the negative terminal last.

   Disconnect all other leads from the alternator and tag each one to ensure correct reinstallation.

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

3. While supporting the alternator, remove the adjusting strap bolt and washers. Then remove the mounting bolts, washers and nuts. Remove the alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the alternator is to be replaced (Fig. 3).

Alternator Service

Repairs and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco–Remy Division, repair service and parts are available through AC Delco branches and repair stations.

Install Alternator

1. Install the drive pulley, if it was removed. Tighten the 5/8" – 18 pulley retaining nut to 70–80 lb–ft (95–108 N·m) torque (Fig. 3).

   NOTICE: If the pulley was not removed, check the retaining nut for proper torque.

2. Position the alternator on the mounting brackets and start the bolts, with washers in place, through the bolt holes in the end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and end frame. Make sure that the washers and nuts are in their proper locations.

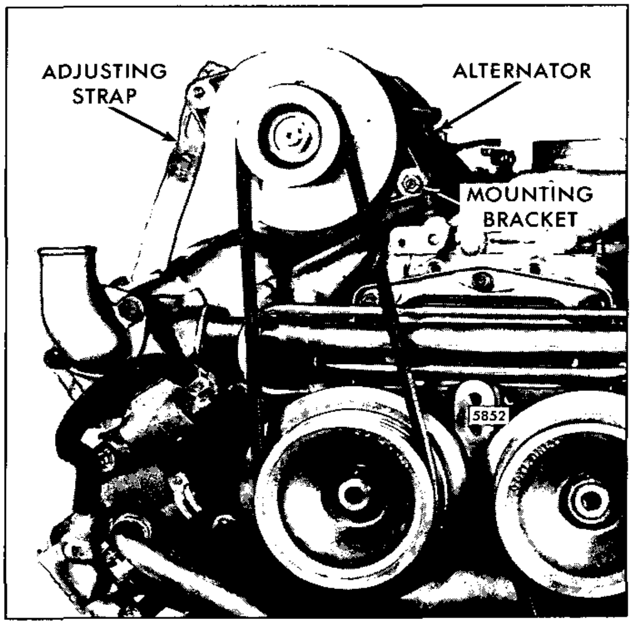


Fig. 2 – Typical Hinge–Mounted Alternator (V–53)

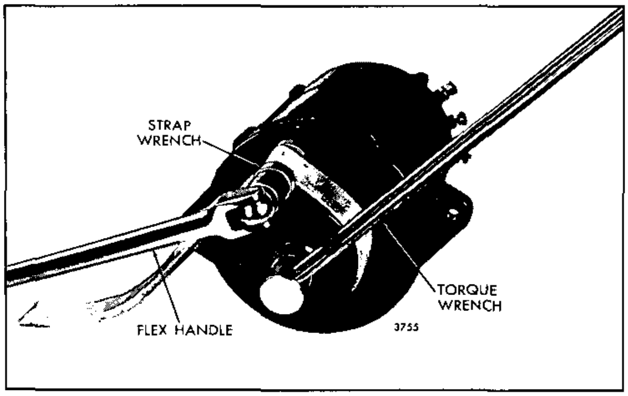


Fig. 3 – Tightening Alternator Pulley Retaining Nut

3. Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the washers, through the slot of the adjusting strap and into the threaded hole in the end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the belt tension as outlined in Section 15.1. After the belt tightening is complete, tighten all mounting bolts.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

• FLANGE–MOUNTED ALTERNATOR (BELTLESS)

The flange–mounted alternator is coupling–driven through a drive hub attached to the blower drive gear. It is a self load limiting alternator with a fully adjustable solid state integral regulator. It is designed with slow speed characteristics which allow lower rotational speed of the alternator without sacrificing any amperage output at idle or top speed. The alternator shaft may be rotated in either direction without affecting the output or cooling of the unit. Six silicon diodes mounted in heat sinks convert alternating current from the delta wound stator into direct current.

The brushes and integral voltage regulator are located in a waterproof housing that may be removed for replacement or inspection.

Alternator Maintenance

1. Keep the mounting bolts securely tightened to prevent vibration damage, which will occur if the mounting bolts loosen.
2. Be sure the plug that seals the integral regulator adjusting hole is in place.

Remove Alternator

1. Disconnect the cables at the battery supply. Disconnect the leads from the alternator and tag each one to ensure correct reinstallation.
2. Loosen the three alternator mounting bolts.
3. While supporting the alternator, remove the mounting bolts, hardened washers and lock washers and lift the alternator and fan guard as a unit from the mounting adaptor. Protect the alternator and fan guard assembly from physical damage following removal from the engine.

NOTICE: The fan guard, which includes an oil seal, should not be separated from the alternator until the alternator half of the coupling is removed. Any attempt to separate the fan guard from the alternator could damage the oil seal.

4. Loosen the retaining nut and remove the coupling hub keyed to the alternator shaft.
5. If the alternator is to be replaced, separate the fan guard from the alternator.
6. Remove the alternator flange mounting adaptor from the flywheel housing, if necessary.

Alternator Service

To service the alternator, contact the alternator manufacturer.

Inspection

Inspect the drive coupling and hub for wear at the seal surface and the drive tangs. If worn excessively, replace them with new parts.

Oil leaks indicate a worn or damaged oil seal. Replace the oil seal in the fan guard, if necessary.

Inspect the alternator housing and flange adaptor at the mounting bolt holes for cracks and the pilot diameters for damage, cracks or distortion. Replace if necessary.

Install Alternator

1. If removed, attach the alternator mounting adaptor, using a new gasket, to the flywheel housing. The adaptor is secured to the engine by two short bolts into

the flywheel housing and four long bolts through the flywheel housing, end plate and blower drive support.

Make sure the alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage. See Section 1.7.7 for alignment procedure.

NOTICE: Special hardened, plain washers seat in the six counterbored bolt holes in the adaptor. Also, the current gasket has a positioning identification tab.

2. If the fan guard and hub were removed, locate the fan guard on the alternator by engaging the mating pilot diameters. Lubricate the seal diameter on the coupling hub and the seal lip. Install the coupling hub on the shaft. Be careful not to damage the lip of the oil seal. Install the retaining nut on the shaft and tighten it to 70–80 lb–ft (95–108 N·m) torque. If the fan guard and hub were not removed, check the retaining nut for proper torque. *Do not support the alternator on the fan guard.*
3. Place the slotted drive coupling on the drive hub. *Align the slotted drive coupling with the blower drive coupling when attaching the alternator assembly.*
4. Align the bolt holes in the fan guard with the mounting holes in the alternator housing. Support the alternator assembly against the mounting flange adaptor, using a new gasket, and install the three 3/8″–16 x 3 1/2″ bolts, lock washers and hardened washers through the alternator housing and fan guard mounting holes into the mounting adaptor. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.
5. Attach the wires and cables. Be sure each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

STORAGE BATTERY

The battery is a device for storing electrical energy and converting chemical energy into electrical energy.

The three basic types of batteries currently being marketed are:

Filler Cap Batteries

These are lead–acid batteries with a high degree of antimony in the grid alloy. They require frequent servicing, especially the need for adding water, as well as cleaning salts from the terminal posts.

Semi–Maintenance Free Batteries

These are conventional filler cap batteries with reduced amounts of antimony in the grid alloy and, consequently, servicing is somewhat reduced. Water must still be periodically added. Terminal posts tend to accumulate salts.

Maintenance–Free Batteries

These batteries use lead–calcium grid construction without antimony. They never need water, nor are provisions provided for adding water. As these batteries have no filler caps to leak acid fumes, terminal posts have less tendency to accumulate salts, and as a result require less frequent cable inspection and cleaning.

The chart below gives the minimum battery capacity recommended for acceptable engine cranking.

Function of Battery

The battery has three major functions:

1. It provides a source of current for starting the engine.
2. It acts as a stabilizer to the voltage in the electrical system.
3. It can, for a limited time, furnish current when the electrical demands exceed the output of the generator or alternator.

NOTICE: In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer.

Install Battery

While the battery is built to satisfactorily withstand the conditions under which it will normally operate, excessive mechanical abuse leads to early failure.

Install the battery as follows:

1. Be sure the battery carrier is clean and that the battery rests level when installed.
2. Tighten the hold–down clamps evenly until snug. However, do not draw them down too tight or the battery case will become distorted or will crack.
3. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal, beneath the cable clamp. Coat the entire connection with a heavy general purpose grease. Be sure the ground cable is clean and tight at the engine block or frame.
4. Check the polarity to be sure the battery is not reversed with respect to the generating system.
5. Connect the *grounded* terminal of the battery last to avoid short circuits which will damage the battery.

Servicing the Battery

A battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for as described below can long and trouble–free service be expected.

1. On filler cap batteries or semi–maintenance free batteries, check the level of the electrolyte regularly. Add water if necessary, but do not overfill. Overfilling can cause poor performance or early failure.
2. Keep the terminal end of the battery clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.

ENGINE MODEL	SYSTEM VOLTAGE	MINIMUM BATTERY RATINGS SAE COLD CRANKING AMPS (CCA) @ 0°F (–17.8°C)
3–53 NA, T; 4–53 NA, T	12, 24, 32	625
6V–53 NA, T	12V	1250
	24V, 32V	625

• Fig. 1 – General Battery Recommendations

3. Inspect the cables, clamps and hold–down bracket regularly. Clean and reapply a coat of grease when needed. Replace corroded or damaged parts.

4. Use the standard battery test (below) as the regular service test to check the condition of the battery.

5. Check the electrical system if the battery becomes discharged repeatedly.

Many electrical troubles caused by battery failures can be prevented by systematic battery service.

Testing Batteries

CAUTION: Battery electrolyte is a solution of sulfuric acid. Avoid contact with clothing, skin, and eyes.

CAUTION: When batteries are being charged and tested, an explosive gas forms inside the battery. Some of this gas escapes through the holes in the vent plugs or vents in the battery cover and may form an explosive atmosphere around the battery itself if ventilation is poor. Sparks or flame can ignite this gas, causing an explosion which can shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

To avoid personal injury, observe these precautions before charging and/or testing a battery:

1. Wear face and eye protection.

2. Have a clean water supply available (to wash off any splashed electrolyte).

3. Provide proper ventilation.

4. Do not test near fire or flame.

Testing Maintenance–Free (Freedom) Batteries

Test each battery separately as follows:

1. Disconnect both terminals of each battery.

2. If battery has threaded stud terminals, use terminal adapters (AC–Delco #ST1201) when testing or charging.

3. Check each battery visually.

4. Examine the hydrometer "eye" (if no eye, proceed to Step 5).

   - Eye shows green – continue test.
   - Eye shows dark – recharge, then continue.
   - Eye shows yellow – replace battery.

5. Apply a 300 amp load for 15 seconds. Turn off load. Wait one minute.

6. If no hydrometer eye, measure terminal voltage (Fig. 2)

   - If 12.4 volts or more – continue.
   - If less than 12.4 volts – recharge, then repeat Steps 5 and 6.

7. Apply a test load of 1/2 CCA rating (in amps). After 15 seconds, with load still applied, measure the terminal voltage. Turn the load off.

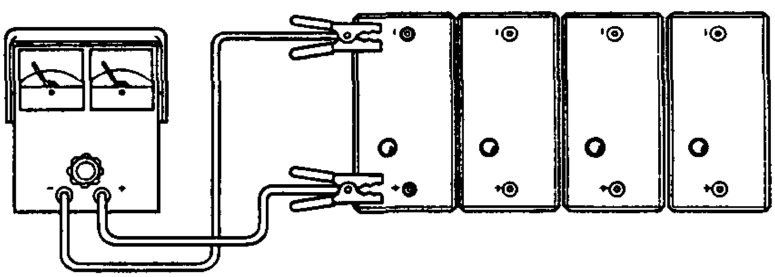


Fig. 2 – Battery Testing

8. Estimate the temperature of the battery. If measured voltage does not meet or exceed the values shown below, replace the battery.

TEMPERATURE	MIN. VOLTS
70°F (21.1°C)	9.6
50°F (10.0°C)	9.4
30°F (1.11°C)	9.1
15°F (-9.44°C)	8.8
0°F (-17.8°C)	8.5

9. Clean all cable ends and terminals of the battery with a wire brush.
10. Tighten the hold–down to specification.

Testing Filler Cap and Semi–Maintenance–Free Batteries

Test each battery separately as follows:

1. Disconnect both terminals of each battery.
2. If battery has threaded stud terminals, use terminal adapters (AC–Delco #ST1201) when testing or charging.
3. Check each battery visually.
4. Check electrolyte level.
   - If fluid is above the top of the plates in all cells, proceed to Step 5.
   - If not, add water, replace vent caps, and charge battery for 15 minutes at 15 to 25 amps to mix electrolyte. Proceed to Step 5.
5. Check specific gravity. If hydrometer readings for all cells are 1.230 or above and show less than 0.050 between high and low at electrolyte temperature of 80°F, proceed to Step 6.
   - If the readings show more than 0.050 difference – replace battery.
   - If the readings show less than 0.050 difference, but some cells read less than 1.230 – recharge battery.
   - If charging won't bring up the specific gravity – replace battery.
6. Remove vent caps and connect 300 amp load for 15 seconds.
   - If a blue haze or smoke is seen in any cell – replace battery.
   - If not, proceed to Step 7.
7. Measure electrolyte temperature and replace vent caps.
   - Connect voltmeter (Fig. 2) and a specific load of one–half the battery's rated CCA.
   - Read voltage after 15 seconds while load is still connected.
   - Disconnect load.
   - Compare voltage reading with the chart below.
   - If voltage is less than the chart, replace battery.
   - If voltage is equal or greater than the chart – the battery is good.

ELECTROLYTE TEMPERATURE	VOLTAGE
70°F (21.1°C)	9.6
60°F (15.6°C)	9.5
50°F (10.0°C)	9.4
40°F (4.44°C)	9.3
30°F (1.11°C)	9.1
20°F (-6.67°C)	8.9
10°F (-12.2°C)	8.7
0°F (-17.8°C)	8.5

8. Clean all cable ends and terminals of the battery with a wire brush.
9. Tighten the hold–down to specification.

STARTING MOTOR

The starting motor (Fig. 1) is mounted on the flywheel housing. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor.

See Section 7.0 for the mounting of a starter auxiliary magnetic switch.

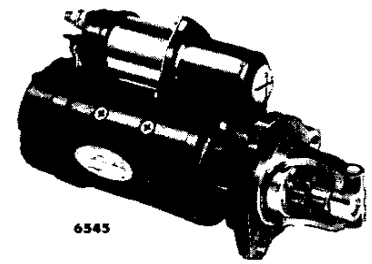


Fig. 1 – Typical Starting Motor

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs, if a twelve hole starter mounting flange is used.
2. Turn the nose housing to the required position.

   NOTICE: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.

3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole starter mounting flange is used.
4. Tighten the screws to 13–17 lb–ft (18–23 N·m) torque.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.
2. Disconnect the starting motor cables and solenoid wiring. *Tag each lead to ensure correct connections when the starting motor is reinstalled.*
3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing. Then, pull the motor forward to remove it from the flywheel housing.

Check the starting motor in accordance with the Delco–Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"–11 starter attaching bolts to 137–147 lb–ft (186–200 N·m) torque when a cast iron flywheel housing is used or to 95–105 lb–ft (129–143 N·m) torque when an aluminum flywheel housing is used.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10–32 connections to 16–30 **lb–in** (2–3 N·m) torque and the 1/2"–13 connections to 20–25 lb–ft (27–34 N·m) torque.

INSTRUMENTS AND TACHOMETER DRIVE

INSTRUMENTS

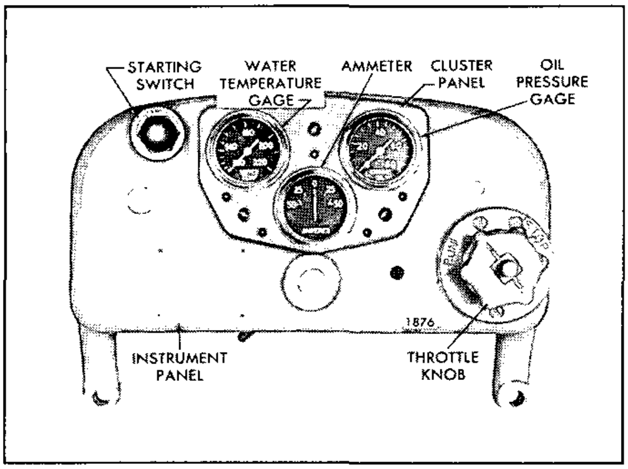


Fig. 1 – Typical Instrument Panel

The instruments generally required in the operation of a diesel engine consist of an oil pressure gage, water temperature gage, an ammeter and a mechanical tachometer. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, engine stop knob and an emergency stop knob (Fig. 1).

All Torqmatic converters are equipped with an oil pressure gage and, in some instances, with an oil temperature gage. These instruments are mounted on a separate panel.

Instruments, throttle control and engine starting and stopping controls are mounted in various locations depending upon the particular use of the engine.

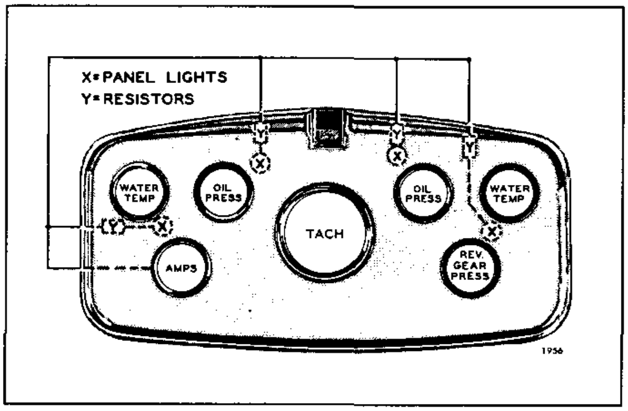


Fig. 2 – Installation of Resistors in Illuminated Instrument Panel

Marine propulsion engines are provided with an instrument panel which usually includes an engine oil pressure gage, reverse gear oil pressure gage, water temperature gage, ammeter and a tachometer. The instrument panels are generally mounted some distance from the engine. Illuminated instrument panels are provided for marine applications which require night operations.

All illuminated instrument panels are wired for a 12 volt lighting circuit. Therefore, when marine propulsion units incorporate either a 24 or 32 volt electrical system, a 12 volt tap–off from the battery may be made, or resistors (Table 1) may be installed in the circuit to protect the instrument panel bulbs. As indicated in Fig. 2, one resistor is used in the lead for each instrument panel bulb.

Resistor Specifications

Volts	Ohms	Watts
24	50	10
32	100	10

TABLE 1

Whenever performing service or preventive maintenance procedures on marine propulsion engine units which include a 24 or 32 volt electrical system, check the lighting circuit of the instrument panels to determine if either a 12 volt tap–off from the battery or resistors have been installed in the lighting circuit to protect the instrument panel bulbs.

Anti–Vibration Instrument Mountings

Anti–vibration mountings are used in many places to absorb engine vibration in the mounting of instruments, drop relays, tachometers, etc. When it may become necessary to service a part secured by rubber mounts, care should be exercised, during removal and installation of the part, so twist is not imposed into the rubber mount diaphram. At the time the part is removed from the engine for service, the mounts should be inspected for damage and replaced, if necessary.

The attaching screw, through the center of the mount, must be held from turning during final tightening of the nut. Support the screw and tighten the nut only. If this screw turns, it will pre–load the rubber diaphragm in torsion and considerably shorten the life of the mount.

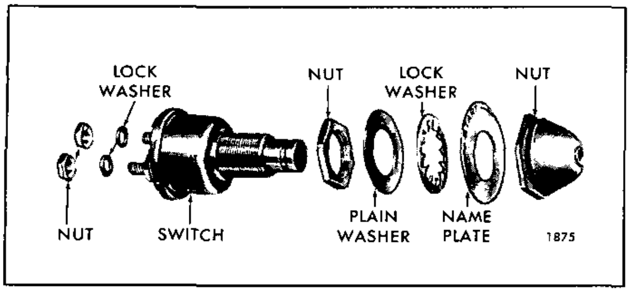


Fig. 3 – Typical Engine Starting Switch

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed in the *Operating Conditions* in Section 13.2, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, a new mounting clamp and connector must be used.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent damage to the gage assembly from vibration, the capillary tube must be securely fastened to the engine the full length with suitable clips at intervals of ten inches or less. Sharp bends in the tube must be avoided, particularly at the gage or bulb connection areas. Where the tube must be bent around any object, the bend must not be less than one inch radius.

Any extra length can be taken up by coiling, the diameter of which should not be less than two inches. The coils must be located so that they may be securely fastened to prevent vibration.

Ammeter

The ammeter is wired into the electrical circuit to show the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in the charge rate to the battery. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. The small current registered prevents rapid brush wear in the battery–charging alternator. If lights or other electrical equipment are connected into the circuit, then the ammeter will show discharge when these items are operating and the engine speed is reduced.

Tachometer

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

Throttle Control

The engine throttle is connected to the governor speed control shaft through linkage. Movement of the speed control shaft changes the speed setting of the governor and thus the engine speed.

Engine Starting Switch

To start the engine, a switch (Fig. 3) is used to energize the starting motor. Starting switches may vary in design and their contacts must be rated sufficiently to carry the starter solenoid current. Tighten the starting switch mounting nut to 36–48 ***lb–in*** (4–5.5 N·m) torque.

Engine Stop Knob

A stop knob is used to shut the engine down. When stopping an engine, the engine speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then pull the stop knob and hold it until the engine stops. Pulling on the stop knob manually *places the injector racks in the no–fuel position. Return the* stop knob to its original position after the engine stops.

> **NOTICE:** When an emergency shut down is necessary on a current engine with the spring loaded fuel injector control tubes, the stop knob should be pulled immediately and held until the engine stops.

Emergency Stop Knob (Engine with Air Shutoff Valve)

In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air shutoff valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine is stopped and the air shutoff valve must be reset manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

A tachometer drive shaft is pressed into the end of the camshaft, balance shaft or governor drive shaft. On V–type engines, it is pressed into the end of either camshaft, the blower drive shaft or the accessory drive gear.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8" threaded connection in place of the former 7/8" connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32" to SAE 3/16". New flexible drive cables are also required with the current tachometers and angle drives.

Remove Tachometer Drive Shaft

If threads (5/16"–24 or 3/8"–24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901–3 on the shaft. Then attach slide hammer J 23907–1 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.

If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then thread a stud into the shaft and remove the shaft with the remover and slide hammer.

NOTICE: Use adequate protective measures to prevent metal particles from falling into the gear train and oil pan.

When installing a tachometer drive cover assembly or a drive adaptor, it is important they be aligned properly with the tachometer drive shaft (Section 7.0).

ENGINE PROTECTIVE SYSTEMS

MANUAL SHUTDOWN

A manually operated emergency engine shutdown device enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the no fuel position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The shutdown device consists of an air shutoff valve mounted in the air inlet housing and a suitable operating mechanism.

Operation

The manually operated shutdown device is operated by a knob located on the instrument panel and connected to the air shutoff valve shaft lever by a control wire. Pulling the knob all the way out will stop the engine. Push the knob all the way in and manually reset the air shutoff valve before starting the engine again.

Service

For disassembly and assembly of the shutdown device, refer to Section 3.3.

AUTOMATIC MECHANICAL SHUTDOWN

The automatic mechanical shutdown system is designed to stop the engine if an abnormal condition such as high engine coolant temperature, low engine oil pressure or engine overspeeding arises. The components of the shutdown system are schematically illustrated in Fig. 1.

A coolant temperature–sensing valve adaptor and plug assembly is mounted on the exhaust manifold with the plug extending into the manifold. Coolant from the engine is directed through the adaptor assembly, in which the bulb of the temperature–sensing valve assembly is located, to the suction side of the water pump.

Oil under pressure from the engine is directed through a restricted fitting to a "T" connection. One line from the "T" is connected to the temperature–sensing valve assembly and the other line leads to the oil pressure bellows. A line attached to the discharge side of the temperature valve directs any oil that passes through the valve to the engine crankcase. Oil under pressure entering the oil pressure bellows, works through the bellows against a spring, overcomes the spring tension and permits the latch to retain the air shutoff valve assembly in the open position. Should the oil pressure drop below a predetermined value, the spring in the oil pressure bellows will release the latch permitting the air shutoff valve to close, stopping the engine. The oil pressure bellows can be adjusted to release the latch at pressures ranging from approximately 5 to 25 psi (34.5 to 172 kPa).

The overspeed governor, used in some engine applications, consists of a small plunger and valve actuated by a set of spring–loaded weights. The plunger and valve are located in the oil line connecting the oil pressure bellows to the main oil gallery. An outlet in the valve is connected to the engine oil sump. Whenever engine speed exceeds the overspeed governor setting, the valve plunger (actuated by the governor weights) is lifted from its seat and permits oil in the line to flow to the engine sump. This results in a drop of oil pressure to the oil pressure bellows, thus actuating the shutdown mechanism and stopping the engine.

Operation

When starting the engine, it is necessary to first manually open the air shutoff valve and then press the engine starting switch, cranking the engine. As soon as the engine starts, the engine starting switch maybe released, but the air shutoff valve must be retained in the open position until the engine oil pressure exceeds the setting of the pressure sensitive device and permits the latch to retain the air shutoff valve in the open position.

During operation, if the oil pressure drops below the setting of the pressure sensitive bellows, the spring within the bellows will release the latch and permit the air shutoff valve to close, stopping the engine.

If the engine coolant overheats during operation, the high temperature will cause the temperature–sensing valve to open and permit the oil to flow to the engine crankcase. *The opening of the temperature–sensing valve lowers the oil* pressure on the discharge side of the restricted fitting. The spring in the pressure sensitive bellows will release the latch and permit the air shutoff valve to close, stopping the engine.

Should the engine lose its coolant during operation, the copper plug extending into the exhaust manifold will heat up and radiate heat to the temperature–sensing valve which will operate and shut the engine down.

Whenever the engine speed exceeds the overspeed governor setting, the oil in the line flows to the sump, resulting in a decrease in oil pressure. The oil pressure bellows will then release the latch and permit the air shutoff valve to close, stopping the engine.

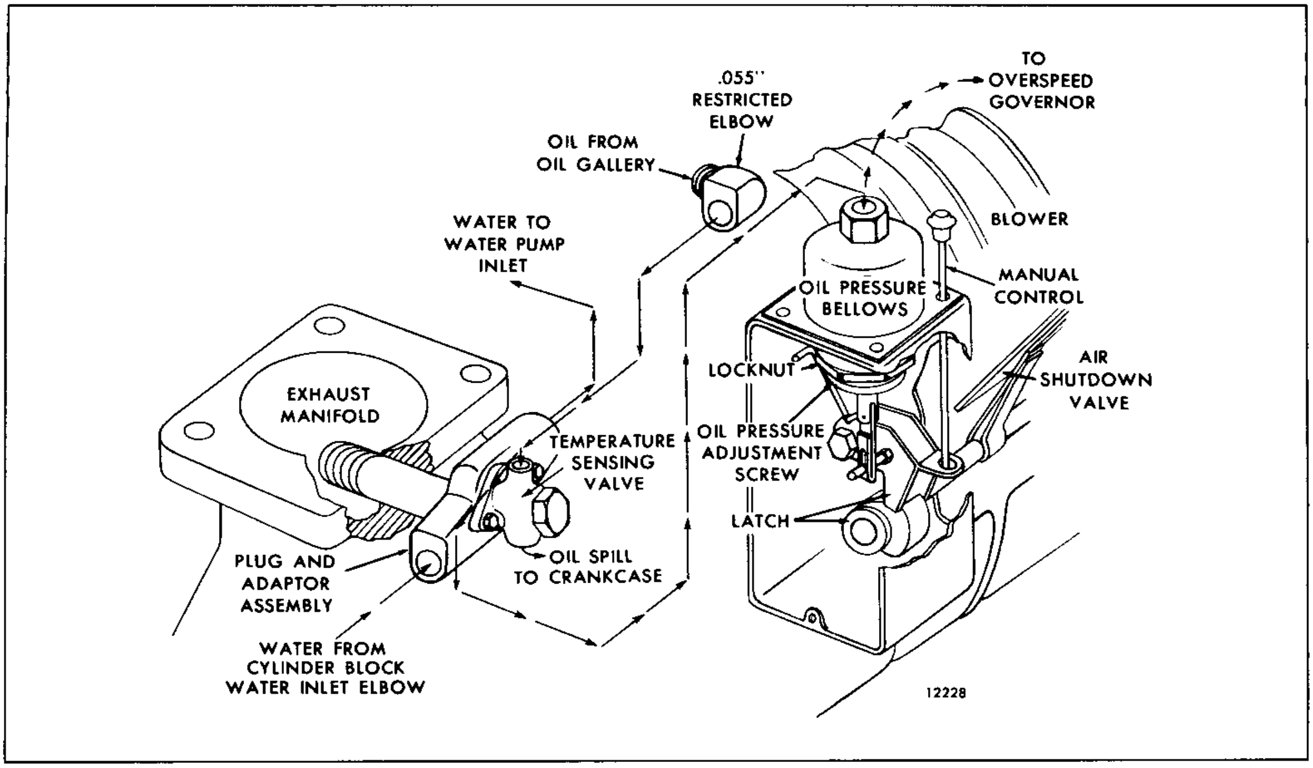


Fig. 1 – Mechanical Shutdown System Schematically Illustrated

After the engine has been stopped due to the action of a protective device, it cannot be restarted until the particular device which actuates the shutdown has returned to its normal position. The abnormal condition which stopped the engine must be corrected before attempting to start the engine again.

Adjustment

The only adjustments necessary in the automatic mechanical shutdown system are the low oil pressure setting of the bellows and the overspeed setting of the overspeed governor. Replace the temperature–sensing valve when operation is unsatisfactory.

To adjust the low oil pressure setting of the bellows, run the engine until normal operating temperature has been reached and the oil pressure has stabilized. Then reduce the engine speed slowly until the bellows disengages the latch on the air shutoff valve and stops the engine. Note the oil pressure at which the shut down occurred. units having a minimum idle speed of 500 rpm it is 10 psi (69 kPa). If adjustment is necessary, loosen the locknut on the bellows and turn the adjusting screw clockwise to increase the oil pressure setting or counterclockwise to decrease the setting. Hold the adjusting screw and tighten the locknut when the proper setting has been obtained.

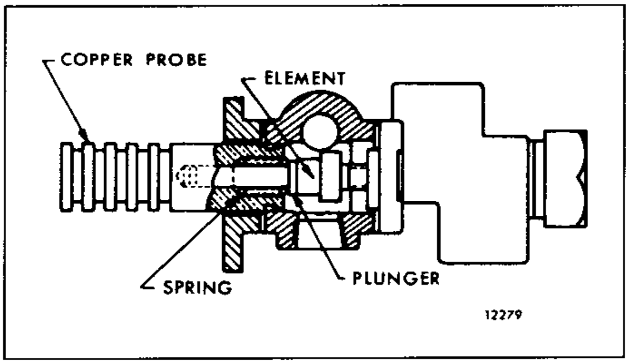


Fig. 2 – Temperature–Sensing Valve

Check the operation of the high coolant temperature–sensing valve by placing a cover over the radiator while the engine is operating at 1800 rpm under load. Observe the coolant temperature on a thermometer inserted at the radiator filler hole. An engine shut down should occur when the coolant is 200° to 210°F (93° to 99°C). If shut down does not occur, replace the coolant temperature–sensing valve assembly. If shut down occurs below 200°F (93°C), check the coolant flow through the plug and adaptor assembly. If circulation is satisfactory and shut down occurs below 200°F (93°C), replace the coolant

temperature–sensing valve assembly. The coolant temperature–sensing valve cannot be adjusted.

NOTICE: If the temperature–sensing valve switch is removed, examine the temperature shutdown valve plunger in the copper probe (Fig. 2). If it is not free in the probe and adaptor, install a new plunger, spring and adaptor. *Deposits from the engine coolant building up* between the plunger, spring and plug can cause the plunger to stick in the probe.

The temperature–sensing valve can be bench tested by attaching an air hose (40 psi or 276 kPa air supply) to the oil inlet side and installing a tube from the outlet side to a can of water. Then, immerse the power element of the valve in a container of water that is heated and agitated.

- **CAUTION: To avoid personal injury when performing this test, wear adequate face and body protection (faceplate, gloves, boots, waterproof apron, etc.).**

Check the temperature of the water with a thermometer. Apply air to the valve. The valve should be open, as indicated by the flow of air, at a water temperature of 195°- 206°F (90°- 99°C).

Overspeed Shutdown Adjustment

1. Start the engine and bring it up to operating temperature.
2. Increase the engine speed to the specified overspeed shutdown speed. At this speed the bellows should disengage the air shutdown latch and stop the engine.
3. Adjust the overspeed governor setting, if necessary, by loosening the governor adjusting screw locknut (on the overspeed governor cap), then turning the adjusting screw clockwise to increase the speed at which the air shutdown mechanism is tripped. Turn counterclockwise to decrease the speed at which the latch will trip. Always tighten the locknut after each adjustment.
4. Stop the engine and replace the control shutdown housing cover.

AUTOMATIC ELECTRICAL SHUTDOWN

The automatic electrical shutdown system (Fig. 3) protects the engine against a loss of coolant, overheating of the coolant, loss of oil pressure or overspeeding. In the event one of the foregoing conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shutdown solenoid to release the air shutdown latch and stop the engine.

Operation

The electrical circuit is de–energized under normal operating conditions. When the engine is started, the oil pressure switch opens when the oil pressure reaches approximately 10 psi (69 kPa) and the fuel oil pressure switch closes at approximately 20 psi (138 kPa) fuel pressure. The water temperature switch remains open.

If the oil pressure drops below 10 psi (69 kPa), the oil pressure switch will close the circuit and energize the shutdown solenoid. This will activate the shutdown mechanism and stop the engine.

A loss of coolant or an increase in coolant temperature to approximately 200°–210°F (93°–99°C) will close the contacts in the water temperature switch, thus closing the electrical circuit and activating the shutdown mechanism.

The water temperature switch consists of a temperature–sensing valve and a micro–switch. The valve contacts a copper plug (heat probe) which extends into the exhaust manifold outlet. Engine water is directed over the power element of the valve and should the water temperature exceed approximately 203°F (94°C), the valve will close the contacts in the micro–switch and energize the shutdown circuit. If a loss of water occurs, the heat of the exhaust gases will be transmitted through the copper plug to the temperature–sensing valve and cause the shutdown circuit to be activated.

If the engine speed exceeds the high speed setting of the overspeed governor, the governor switch will close and activate the shutdown mechanism.

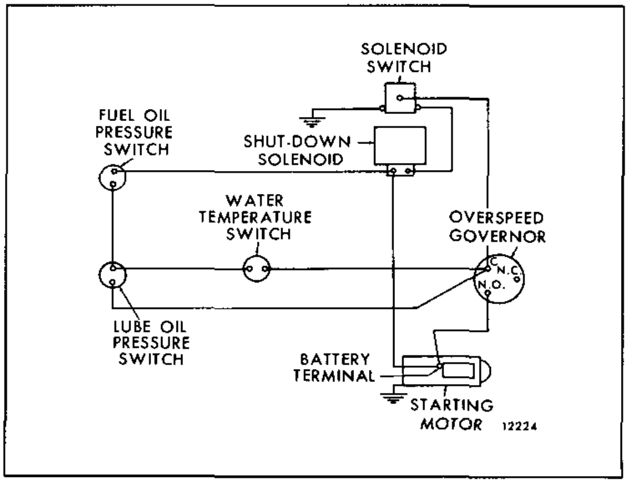
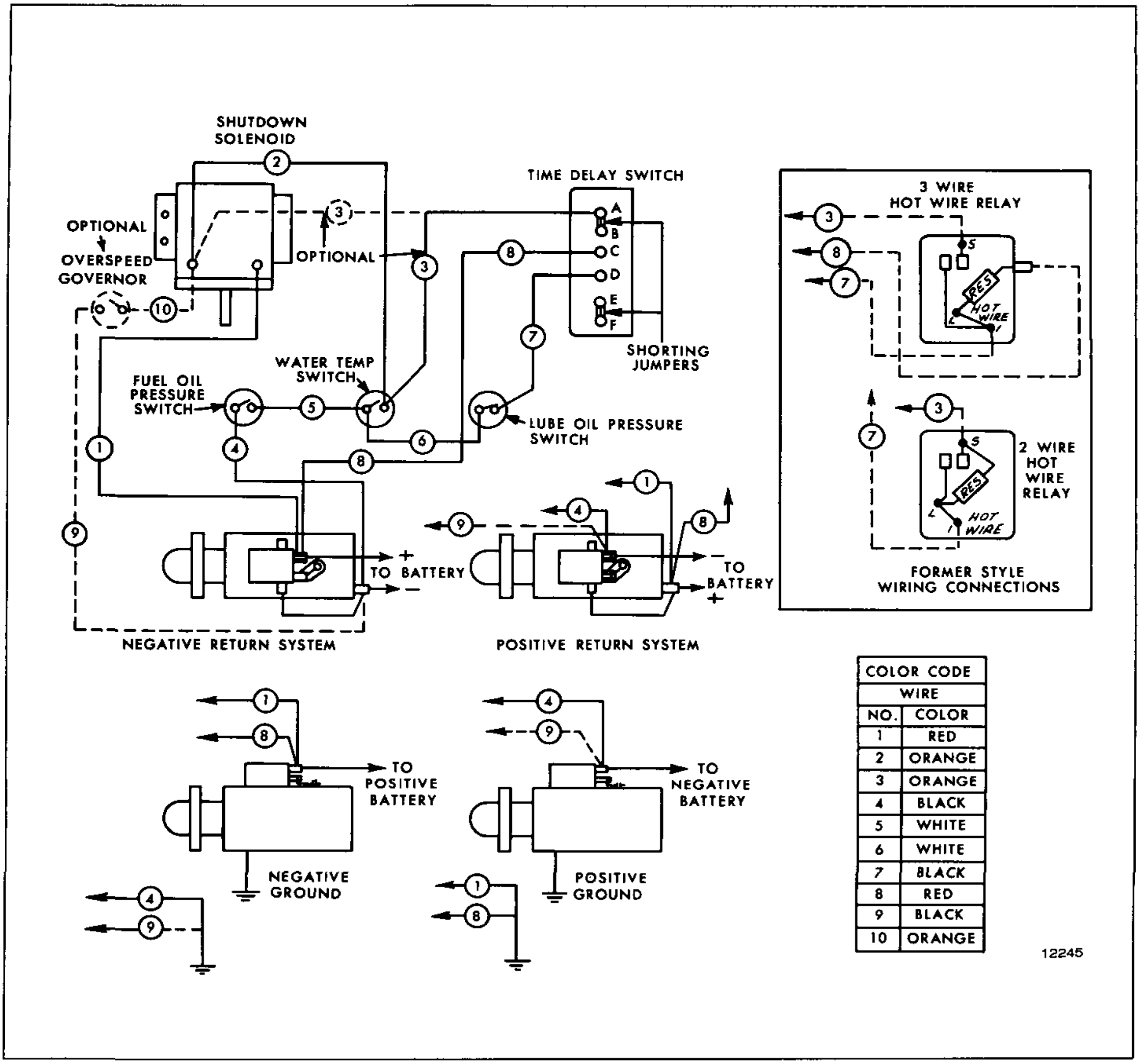


Fig. 3 – Automatic Electrical Shutdown System Diagram



COLOR CODE	
WIRE	
NO.	COLOR
1	RED
2	ORANGE
3	ORANGE
4	BLACK
5	WHITE
6	WHITE
7	BLACK
8	RED
9	BLACK
10	ORANGE

Fig. 4 – Automatic Electrical Shutdown System Incorporating Hot Wire Relay or Time Delay Switch

When the engine is shutdown, the decrease in speed will open the governor switch and the decrease in oil and fuel pressures will close the oil pressure switch and open the fuel pressure switch, thus de–energizing the circuit.

The cause of the abnormal conditions must then be determined and corrected before the engine is started again. Also, the air shutoff valve must be manually reset in the open position before the engine can be started.

Some engines are equipped with an electrically operated automatic shutdown system which incorporates a hot wire relay or solid state time delay switch (Fig. 4).

Since the fuel pressure builds up rapidly, the fuel oil pressure switch could close before the lubricating oil pressure switch opens, thereby effecting a shutdown of the engine. The hot wire relay or time delay switch, however, delays the closing of the fuel oil pressure switch for 3 to 10

seconds to enable the lubricating oil pressure to build–up and open the oil pressure switch contacts.

When the lubricating oil pressure falls below 10 $\pm$ 2 psi, the contacts in the oil pressure switch used in this system will close and current will flow to the hot wire relay or the time delay switch. The few seconds required to heat the hot wire relay provides sufficient delay to avoid an engine shutdown when low oil pressure is caused by a temporary condition such as an air bubble or a temporary overlap in the operation of the oil pressure switch and the fuel oil pressure switch when starting or stopping the engine.

The high water temperature switch is installed in the side of the thermostat housing. The switch contacts close when the water temperature reaches approximately 205°F (95°C).

Solid State Time Delay Switch

The current solid state time delay switch is designed as a direct replacement for the former hot wire relay (Fig. 4).

It is a solid–state time device which effectively withstands shock and vibrations. The switch is polarity–conscious. If a reverse polarity is applied the switch will not work.

The switch has two circuits: a time circuit and an electronic circuit which consists of a silicon control rectifier. The rectifier has sufficient capacity to handle standard loads such as the emergency shutdown solenoid. Abnormal load situations such as a collapsing magnetic field in a coil can damage the rectifier rendering it inoperative. To protect the rectifier a discharge diode is connected across the terminals B and C of the solid state time delay switch.

The time delay switch should be check periodically to be sure that it is operating properly (refer Section 7.0).

SHUTDOWN SYSTEM FOR DIRECT MOUNTED TURBOCHARGED ENGINES

With the use of a direct mounted turbocharger and the spring loaded fuel injector control racks, the air shutoff valve was eliminated from the air inlet housing. The spring loaded injector tube control rack enables the engine to come out of any advanced fuel position when an emergency situation arises.

When an engine is operating in an atmosphere subject to volatile fuel and is equipped with an air inlet housing without the air shutoff valve, a customer may request that the engine be equipped with an external or remote mounted emergency air shutdown assembly.

The remote mounted emergency air shutdown assembly that is equipped with the air shutoff valve can be installed upstream of the air inlet side of the turbocharger.

Care should be taken when installing the emergency air shutdown assembly between the turbocharger and the air cleaner. Because the engine shutdown system is activated, all of the piping between the shutdown system and the engine will be subjected to an abnormally high suction which may cause some of the piping components, i.e., rubber hoses and elbows to collapse. Therefore, it is recommended that all of these components be designed to withstand the maximum suction without a failure which would allow air to reach the engine air intake.

A 7 to 5 inch diameter reducing 90° rubber hose or a 7 to 5 inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

The rubber elbow can be obtained from the manufacturer; Griffin Rubber Mills in Portland, Oregon under their part number – 51759.

The customer is required to provide the mounting support brackets.

The emergency air shutdown assembly is manually operated. To be an automatic shutdown system, it will be necessary to install a solenoid.

ALARM SYSTEM

The alarm system is similar in many respects to the automatic shut–down system, but does not include the automatic shut–down feature incorporating the electrical solenoid or the flap valve in the air shut–down housing which is operated by the solenoid. A bell is substituted for the solenoid in the alarm system. The alarm may be substituted for the shut–down solenoid, or it may be added to the automatic shut–down system. In either case, the alarm notifies the operator of a dangerous condition in the engine.

The voltage used through the alarm bell, however, *must not exceed 12 volts.*

Note that the cranking motor performs no essential function in the circuit.

An oil pressure switch, introduced into the engine oil gallery, is closed when the engine is not running, but opens after starting and remains open while the engine is running. This switch will close only in case of lowered oil pressure, thus causing the alarm to operate, or it will close if the engine is stopped by the operator. A water temperature switch always remains open except in case of high water temperature when it closes and operates the alarm.

An automatic fuel oil switch closes after the engine is started and normal fuel oil pressure has been attained.

An optional overspeed switch is sometimes introduced into the system.

The water temperature switch and the oil pressure switch are similar to the same switches used in the automatic shut–down device.

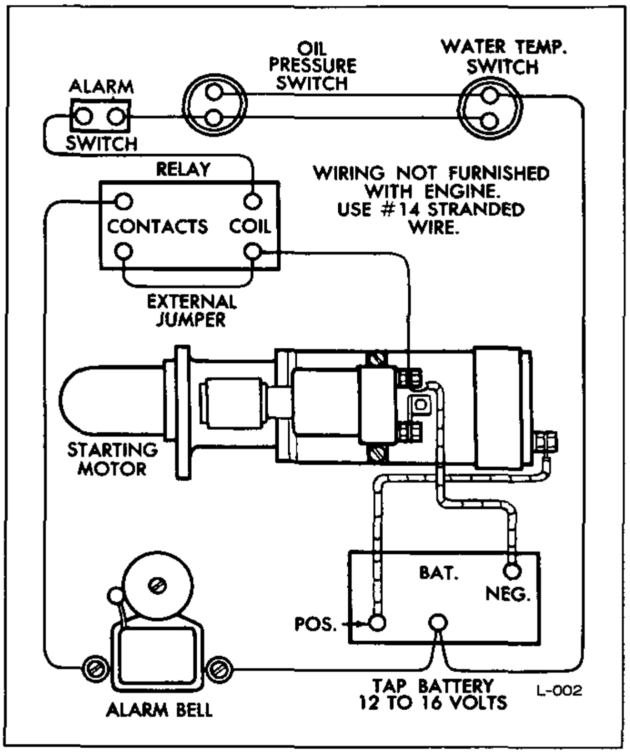


Fig. 1 – Alarm System Wiring Diagram

Service of the alarm system is usually limited to replacement of the alarm bell.

OVERSPEED GOVERNORS

ELECTRIC (TWO SWITCH)

The series GY–2 Snychro–Start overspeed governor (Fig. 1) contains two separate snap action switches with single–pole double–throw contacts which operate at two different speeds. The governor is adjusted by the manufacturer to trip at the speeds required as indicated on the name plate. Unless otherwise specified, the name plate indicates trip points on increasing speed. The contacts will return to normal when the speed is decreased approximately 100 rpm below the trip speed, except on the high speed switch of those models having a manual reset button. The letter "M" after any model number indicates the high speed switch must be reset manually.

Service

1. The snap action switches may be replaced as follows:

   a. Mark the position of the dust cover and remove both hold–down screws.

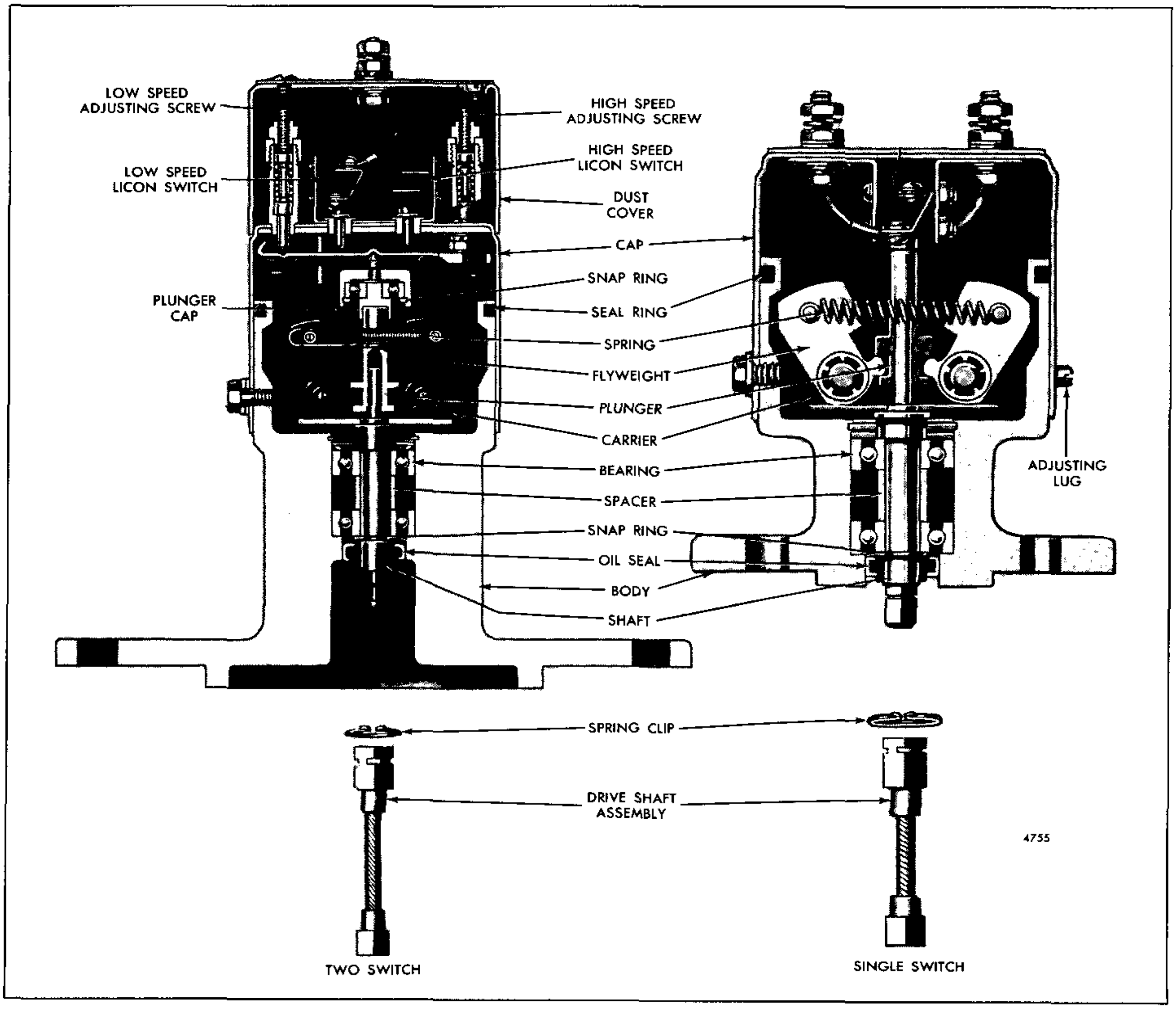


Fig. 1 – Electric Overspeed Governors

b. Observe the position of the switches. Usually they are positioned with 1/64″ clearance between the switch button and the lifters. If the lifters are replaced, make certain that the long lifter is placed beneath the low speed switch and the short lifter is placed beneath the high speed switch.

c. Install the new switches by reversing the above procedure. When replacing the dust cover on a governor with a manual reset, make certain the switch wiring does not interfere with the reset mechanism.

d. Adjust the speed as outlined under *Speed Adjustment.*

2. Remove the governor cap as follows:

a. Observe the marking on the cap and the body and remove the three holding screws.

b. Remove the cap assembly, being careful not to damage the seal ring.

c. Replace any internal parts as required and reassemble and return the cap to the original position. A light coat of grease will facilitate assembly of the seal ring to the body.

The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1000 rpm and the trip point of the high speed switch is above 2100 rpm. These governors use elongated loop flyweight springs. If, after assembly, the No. 1 switch trips at a far higher point than normal, lower the cap position slightly. If the No. 2 switch trips at a very low speed, raise the cap position slightly. If difficulty arises, refer to Step 5 below.

d. Adjust the speed as outlined under *Speed Adjustment.*

3. Replace the speed adjusting springs as follows:

a. Hold the speed adjusting stud with a 5/16″ open end wrench and loosen the adjusting stud nut with a 3/8″ open end wrench.

b. After the above nut is removed, the adjusting spring and related parts may be removed and replaced as necessary. Exercise care to prevent particles of dirt from accumulating on the parts.

4. Replace the flexible drive shaft as follows:

a. Insert a sharp pointed instrument in the loop of the spring clip and pull it from the shaft as far as possible and remove the shaft assembly.

b. Upon reassembly, first install the spring clip in the groove of the fitting on the end of the governor shaft.

c. Push the shaft assembly into the square end of the governor shaft and the spring clip will snap in place.

Check the position of the spring clip. If the clip has sprung out of position, use a small screw driver to push it into place.

5. Adjust the governor cap (with the dust cover in place):

a. Turn the low speed adjusting screw out for minimum speed adjustment. In this position, the top of the adjusting screw is approximately 1/8″ from the top of the dust cover.

b. Turn the high speed adjusting screw in for almost maximum speed adjustment. In this position, the top of the adjusting screw is approximately 5/16″ from the top of the dust cover.

c. With partial tension on the cap holding screws, turn the governor cap to the maximum extended position.

d. Operate the governor at 200 rpm above the trip point of the low speed switch.

e. Rotate the cap slowly in a clockwise direction until the low speed switch trips, mark the cap position and stop the engine. Then turn the cap another 1/16″ and lock the holding screws securely.

f. Complete the operation as outlined under *Speed Adjustment*. Generally, the trip point of the low speed switch will have to be increased and the high speed switch decreased.

Maintenance

Grease the governor shaft ball bearings every 10,000 hours (every 5,000 hours if the governor speed is above 2500 rpm) as follows:

1. Remove the governor cap.
2. Remove the flexible drive shaft.
3. Remove the retaining ring from the groove in the housing. Then remove the weight and shaft assembly.
4. Inspect the oil seal and, if necessary, replace it as follows:

a. Place the governor body in an arbor press, with the mounting flange toward the bottom, and use a 9/16″ diameter rod to press the oil seal out.

b. Press a new seal in place 3/64″ from the bottom of the bearing cavity.

5. Fill the grease reservoir between the bearings *only 3/4 full* with Texaco "Unitemp" grease, or equivalent.

6. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speeds as outlined below:

Speed Adjustment

Both switches may be individually adjusted. The dust cover screw marked "1" covers the low speed adjuster; the screw marked "2" covers the high speed adjuster. Proceed as follows:

1. Remove the appropriate dust cover screw. Then insert a 1/16″ Allen wrench into the adjusting screw.

2. Turn the screw clockwise to increase the trip speed or counterclockwise to decrease the speed.

NOTICE: If the adjusting screws are turned in too far, the switch will no longer operate. Do not attempt to use the slots in the cap for normal speed adjustments. This position is set and marked by the manufacturer for operation in the speed range required.

ELECTRIC (SINGLE SWITCH)

Series GWA, GYA and GAA Synchro–Start overspeed governors (Fig. 1) are calibrated by the manufacturer to open or close the switch contacts at the particular speed required. The switch contacts will reset automatically when the speed is reduced approximately 100 rpm below the trip speed.

Service

Grease the governor shaft ball bearings every 10,000 hours (every 5000 hours if the governor speed is above 2500 rpm) as follows:

1. Remove the adjusting screw and the adjusting stud, then remove the governor cap.

2. Insert a sharp pointed instrument in the loop of the spring clip and pull the clip from the flexible shaft as far as possible. Then remove the shaft assembly.

3. Remove the retaining ring from the groove in the housing.

4. Remove the weight and shaft assembly.

5. Inspect the oil seal and, if necessary, replace the seal as follows:

   a. Place the governor body in an arbor press with the mounting flange facing down and use a 9/16″ diameter rod to press the oil seal out of the body.

   b. Press the new oil seal in place, 3/64″ from the bottom of the bearing cavity.

6. Fill the grease reservoir between the bearings *only 3/4 full* with Texaco "Unitemp" grease, or equivalent.

7. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speed as outlined below.

Speed Adjustment

Loosen the cap adjusting lock screw and turn the cap until the desired trip speed is reached. Clockwise rotation of the cap lowers the trip speed and counterclockwise rotation increases the trip speed. The total range of adjustment of the particular governor is indicated on the governor name plate. The governor should not be adjusted to trip below 100 rpm above the normal running speed of the governor. Make sure the governor cap locking screw is tightened after the adjustment has been completed.

NOTICE: Under no circumstances should the governor switch be by–passed to prevent engine shut–down in the event of overspeed. Serious damage to the engine and the governor may result, since the governor is not designed to operate above its tripping speed.

HYDRAULIC

The hydraulic overspeed governor which contains a set of spring–loaded weights prevents excessive engine speeds.

Figure 2 illustrates the old and new hydraulic overspeed governors. The new governor differs from the old governor in the use of a new housing, cover and speed adjusting screw. The new housing is shorter and the new cover is longer than the old cover. The new adjusting screw differs from the former screw in the width of the seal ring groove which is wider on the new screw.

The overspeed governor is mounted in an adaptor which is mounted on the rear of the flywheel housing. A seal ring in the adpator end of the governor housing prevents oil seepage from the flywheel housing. The governor is driven by

a flexible drive assembly from the blower drive shaft. Oil under pressure is supplied to the governor by a tube which is connected to the oil gallery in the cylinder block.

Operation

When the engine speed reaches the value for which the overspeed governor is set, the centrifugal force of the weights in the overspeed governor overcomes the spring tension and opens a pilot valve in the governor. The pilot valve dumps oil from the oil tube, lowering the pressure at the engine oil pressure switch, thus closing the switch and energizing the shut–down solenoid and closing the shut–down valve.

Lubrication

The overspeed governor is lubricated by oil from the engine crankcase.

Adjustment

The engine shut–down speed is determined by the position of the adjusting screw in the overspeed governor cover. To change the setting, loosen the lock nut and turn the adjusting screw in to increase the speed or out to decrease the speed. When the proper setting is obtained, tighten the adjusting screw lock nut.

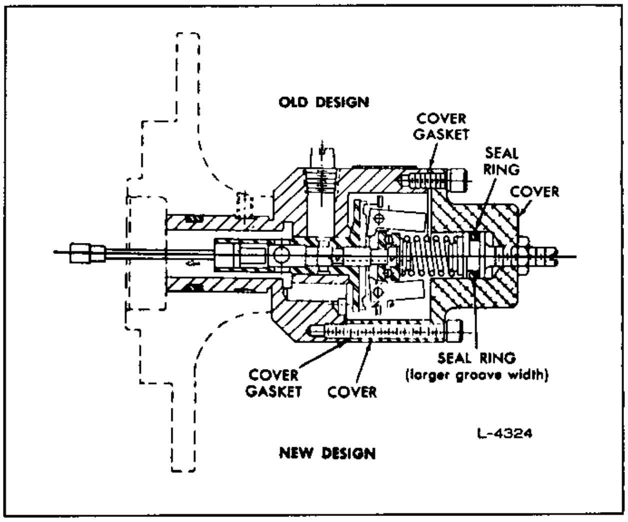


Fig. 2 – Hydraulic Overspeed Governor

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

PROPER OPERATION OF THE SWITCHES OR ALARM SYSTEM FOR TESTING THE ELECTRICAL SHUTDOWN

The protective system is activated whenever low lubricating oil pressure, high coolant temperature, engine overspeed or any other abnormal condition develops that could damage the engine.

In a properly maintained installation, the shutdown system seldom has cause to function. Therefore, it is advisable to check the system periodically to be sure that it will function when needed.

Check each component of the shutdown system as outlined below. It is important to thoroughly warm-up the engine before any component of the shutdown system is checked.

Overspeed Governor

1. Remove the valve rocker cover. Discard the gasket.
2. Start the engine and move the speed control lever to the *full-speed* position.
3. While watching a tachometer, manually move the control tube slowly towards the *increased fuel* position until the air shutoff valve closes, stopping the engine. Do not exceed the engine no-load operating speed by more than 10%.
4. Note the speed at which the engine stops and adjust the overspeed governor, if necessary, as outlined in Section 7.4.3.
5. Using new gaskets reinstall the valve rocker cover.

Water Temperature Switch

The terminals of the water temperature switch are connected into the shutdown system and when the engine water temperature reaches 210°F (99°C), the switch closes and completes the circuit in the shutdown or alarm system.

1. Cover the radiator with a sheet of cardboard to prevent circulation of air.
2. Remove the radiator cap, if the engine is operating near sea level, and insert a steel jacketed thermometer.

The boiling point of water lowers approximately 2° for each 1000 foot rise in altitude. As an example, water boils at approximately 203°F (95°C) at 5000 feet and at 195°F (91°C) at 9000 feet altitude. It is necessary to retain the radiator pressure cap on engines which operate in excess of 1000 feet altitude to prevent the coolant from boiling while performing this test. The engine temperature gage, if it is found to be accurate, may be used when performing this test.

Do not exceed 210°F (99°C) when *performing this test*.

3. Start and run the engine at rated speed and with enough load to raise the water temperature gradually until the air shutoff valve closes. The water temperature switch will usually be set at 210°F (99°C).
4. Note the temperature at which the air shutoff valve closed.
5. Remove the radiator cover and start the engine without load immediately after the engine stops. This will permit the engine to cool down to normal operating temperature.

Fuel Oil Pressure Switch

The fuel oil pressure switch is set to make contact at an increasing fuel pressure of 20 psi (138 kPa). The phrase "20-MAKE" is stamped on the switch cover.

As the fuel pressure increases upon starting the engine, a diaphragm in the switch body expands and forces the plunger upwards (Fig. 1). Since the bottom of the adjusting screw bears against this plunger, the adjusting screw and the lower breaker point are also forced upwards. When the fuel pressure reaches 20 psi (138 kPa), the breaker points close and current flows to the terminals of the lubricating oil pressure switch and the water temperature switch.

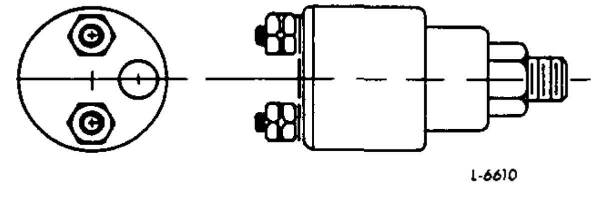


Fig. 1 - Fuel Oil Pressure Switch

When the engine is stopped, the fuel pressure decreases and the diaphragm in the switch body contracts. This action causes the plunger to lower and, when the fuel pressure decreases to 20 psi (138 kPa), permits the lower breaker point arm to lower and break the electrical circuit. The bracket to which the lower breaker point arm and the adjusting screw are attached is spring–loaded, which provides for positive breaking of the connection when the fuel pressure decreases sufficiently.

1. Insert a pressure gage on the discharge side of the fuel strainer.
2. Remove one of the leads from the lubricating oil pressure switch while this test is being performed, to prevent the engine from being shut down.
3. Start and run the engine at idle speed.
4. Slow the engine down by moving the speed control lever towards the *no–fuel* position until the fuel pressure is approximately 15 psi (103 kPa), with the engine barely turning over.
5. Place a jumper wire across the water temperature switch terminals.
6. Raise the engine speed slowly and watch the fuel oil pressure gage until the air shutoff valve closes.
7. Note the fuel pressure at which the air shutoff valve closed and, if necessary, replace the switch.
8. Remove the jumper wire from the water temperature switch and reconnect the lubricating oil pressure switch.

Lubricating Oil Pressure Switch

The construction of the lubricating oil pressure switch is very similar to that of the fuel oil pressure switch, except that the lubricating oil pressure switch is calibrated to break contact when the lubricating oil pressure increases to 10 psi (69 kPa). The phrase "10 BREAK" is stamped on the switch cover.

A 20 psi (138 kPa) break switch is used on some engines whose predominant operation is constant speed.

As the lubricating oil pressure increases upon starting, the diaphragm in the switch body expands and forces the plunger upwards (Fig. 2). Since the bottom of the adjusting screw bears against the plunger, and the adjusting screw is attached to the bracket which controls the upper breaker point arm, the arm is also forced upwards. When the lubricating oil pressure increases to 10 psi (69 kPa), the points separate. Current flows to the lubricating oil pressure switch only after the fuel oil pressure switch closes, at which time the points of the lubricating oil switch are open. Should the lubricating oil pressure decrease to 10 psi (69 kPa) during operation, the breaker point will close and either the alarm bell or shutdown solenoid will be energized.

1. Start and run the engine at idle speed.

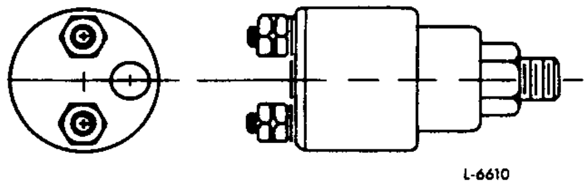


Fig. 2 – Lubricating Oil Pressure Switch

2. Place a jumper wire on the hot wire relay between the "1" and "S" terminals.
3. Place a jumper wire across the fuel oil pressure switch terminals.
4. Reduce the engine speed by moving the control lever towards the *no–fuel* position while watching the lubricating oil pressure gage.
5. Note the oil pressure at which the switch stops the engine and, if necessary, replace the switch.
6. Remove the jumper wire.

Hot Wire Relay

1. Start and operate the engine at idle speed.
2. Place the jumper wire across the terminals of the lubricating oil pressure switch while watching a second hand of a clock.
3. Not more than three (3) to ten (10) seconds should elapse between the time the jumper wire is placed across the terminals of the lubricating oil pressure switch and the air shutoff valve closes.

The above procedures completely test the normally open electrical shutdown system on an engine.

> **NOTICE:** When the engine is operating at idle speed or above, the air shutoff valve will completely close off the air from the engine causing it to stop. However, when the engine is operating at the very low speeds that are necessary when performing the test on the fuel shutdown switch and the lubricating oil shutdown switch, the air damper solenoid will close the air shutoff valve, but the engine may continue to run very slowly. This may be due to insufficient force exerted by the low air flow on the back of the shutoff valve to completely close it.

Solid State Time Delay Switch 12, 24 or 32 Volts–Direct Current

A solid state time delay switch is used on current engines in place of the former hot wire relay.

A bench test procedure for the solid state time delay switch (Fig. 3) is as follows:

1. Remove the time delay switch from the engine.
2. Install the jumper straps on terminals "A" to "B" and "E" to "F", if they have been removed. Normally, the jumper straps are on the Time Delay Switches as supplied.
3. Install a positive battery lead to terminal "A".
4. Install a negative battery lead to one side of a 12 volt light which is a known good test lamp.
5. Install a lead from the opposite side of the light to terminal "D". A switch may be used in this lead, if desired.
6. After the negative lead is connected to "D" or the switch is closed, the lamp should light in eight (8) to ten (10) seconds. If not, the time delay switch must be replaced.

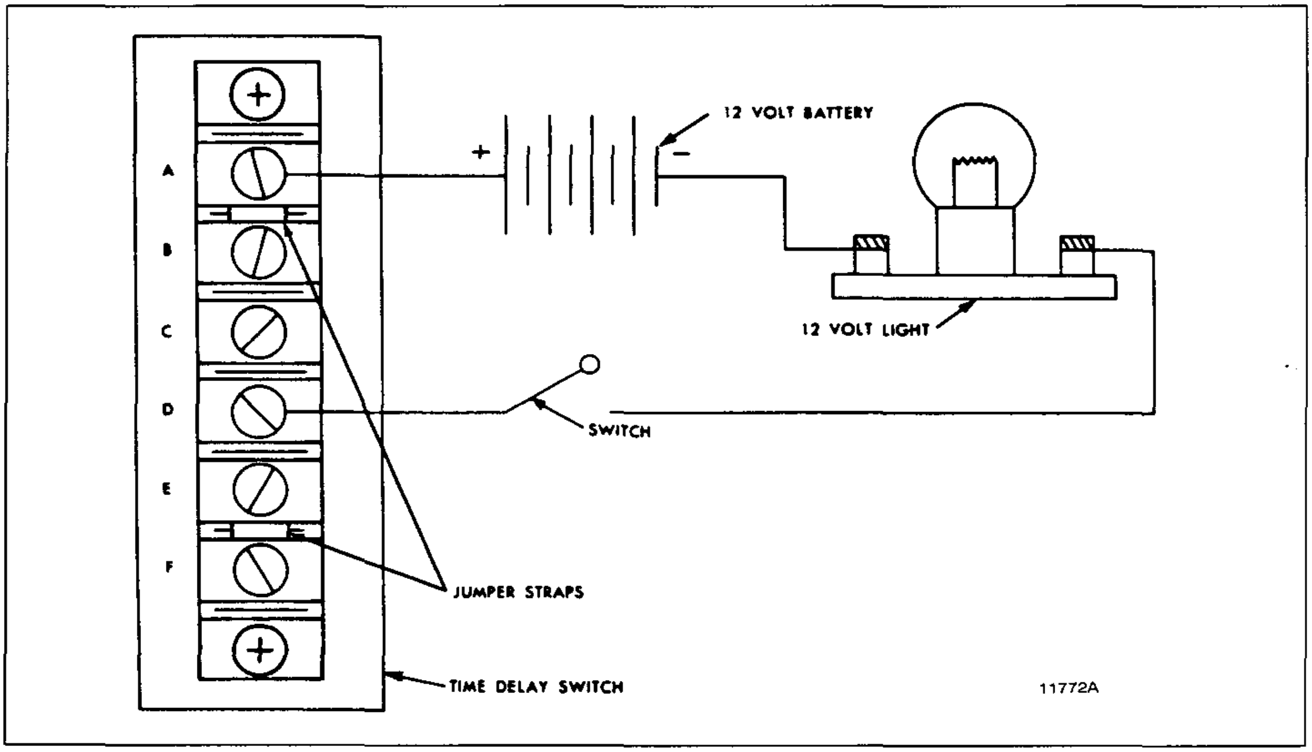


Fig. 3 – Time Delay Switch Testing Diagram

CHECK ENGINE STARTING SWITCH

If difficulty in starting motor engagement has been experienced in a vehicle which has been repowered by a diesel engine, check to see if the key–type starting switch on the instrument panel has been retained.

Key–type starting switches are usually not capable of carrying the current required for heavy–duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and results in failure of the starter to engage and crank. When tooth abutment occurs and the switch is turned off and on several times, breaking of the solenoid current causes burning or welding of the switch contacts.

Install a push button type starting switch which is capable of making, breaking and carrying the solenoid current without damage (refer to *Engine Starting Motor Switch* in Section 7.4). Otherwise, a heavy–duty magnetic switch should be used in the solenoid control circuit in addition to the key–type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12 volt system; the key switch would then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed on a engine, it is important that the cover assembly or adaptor be aligned properly with the tachometer drive shaft.

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adaptor resulting in possible gear seizure and damage to other related components.

Use one of three tools in set J 23068 to establish the proper alignment. Fig. 4 illustrates the use of the tools.

Because of the many different combinations of tachometer drive shafts, covers and adaptors, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool.

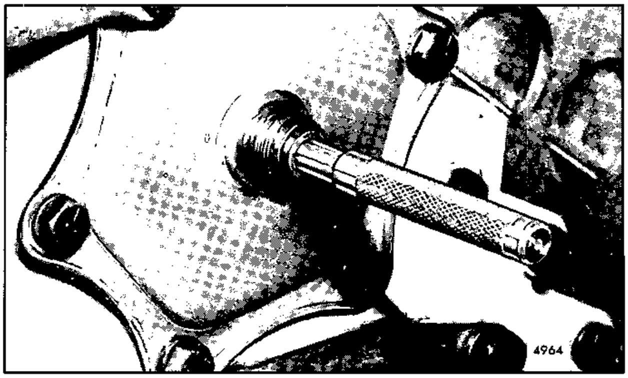


Fig. 4 – Checking Tachometer Drive Shaft Alignment

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

MOUNTING THE STARTER AUXILIARY MAGNETIC SWITCH

On certain railcar and highway units equipped with Detroit Diesel engines and Delco–Remy starter auxiliary magnetic switches, no–start conditions may result from damage to the starter auxiliary magnetic switch caused by vibration. The vibration may result from improper mounting of the auxiliary magnetic switch.

The following guidelines should be followed when mounting a Delco–Remy starter auxiliary magnetic switch (Fig. 5):

1. Do not mount the switch on the engine.
2. Position the mounting pads of the switch vertically (one above the other).
3. Mount the switch on a rigid bracket, base rail or fire wall.

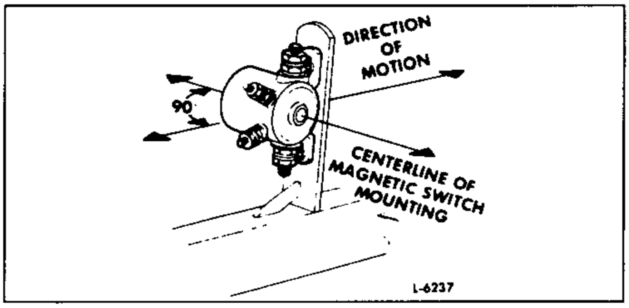


Fig. 5 – Starter Auxiliary Magnetic Switch Mounting

4. Mount the switch on a surface perpendicular (90°) to the forward motion of the vehicle so that contact disc movement is not in line with gravity or vehicle movement.

TROUBLESHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the electrical generating system, the following quick checks can be made to assist in localizing the cause.

A *fully charged battery and low charging rate* indicates normal alternator–regulator operation.

A *low battery and high charging rate* indicates normal alternator–regulator operation.

A *fully charged battery and high charging rate* condition usually indicates the voltage regulator is set too high or is not limiting the alternator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

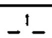
A *low battery and low or no charging rate* condition could be caused by: Loose connections or damaged wiring, defective battery or alternator and defective regulator or improper regulator setting.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255–M	1	No. 6 thru 1 1/2	60,000
None	GM 260–M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
 Bolts and Screws	GM 280–M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
 Hex Head Sems Only	GM 275–M	5.1	No. 6 thru 3/8	120,000
 Bolts and Screws	GM 290–M	7	1/4 thru 1 1/2	133,000
 Bolts and Screws	GM 300–M	8	1/4 thru 1 1/2	150,000
 Bolts and Screws	GM 455–M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb–ft)	TORQUE (lb–in)	TORQUE (N·m)
Tachometer drive cover bolt	7/16–14	30–35		41–47
Starting motor connector	1/2–13	20–25		27–34
Tachometer drive cover bolt	1/2–13	30–35		41–47
Starting motor connector	No. 10–32	—	16–30	2–3.5
Tachometer drive shaft (blower)	1/2–20	55–65		75–88
Starting motor attaching bolts (alum. flywheel hsg.)	5/8–11	95–105		129–143
Starting motor switch mounting nut	5/8–32	—	36–48	4–5.5

SERVICE TOOLS

TOOL NAME	TOOL NO.
Puller set	J 5901–01
Tachometer drive shaft remover	J 5901–3
Tachometer drive alignment tool set	J 23068

SECTION 8

POWER TAKE-OFF - TORQMATIC CONVERTER

For service and overhaul procedures for Allison products, contact the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

For service and overhaul procedures for Rockford products, contact the manufacturer:

Rockford Powertrain, Inc.
1200 Windsor Rd.
P. O. Box 2908
Rockford, IL 61132-2908

SECTION 9

TRANSMISSIONS

For service and overhaul procedures for Allison products, contact the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

For service and overhaul procedures for Twin Disc products, contact the manufacturer:

Twin Disc, Inc.
1328 Racine Street
Racine, Wisc. 53403

For service and overhaul procedures for Warner Gear products, contact the manufacturer:

Borg–Warner Automotive, Inc.
Transmission Systems
P.O. Box 2688
Muncie, IN 47302

SECTION 12

SPECIAL EQUIPMENT

CONTENTS

BILGE PUMP

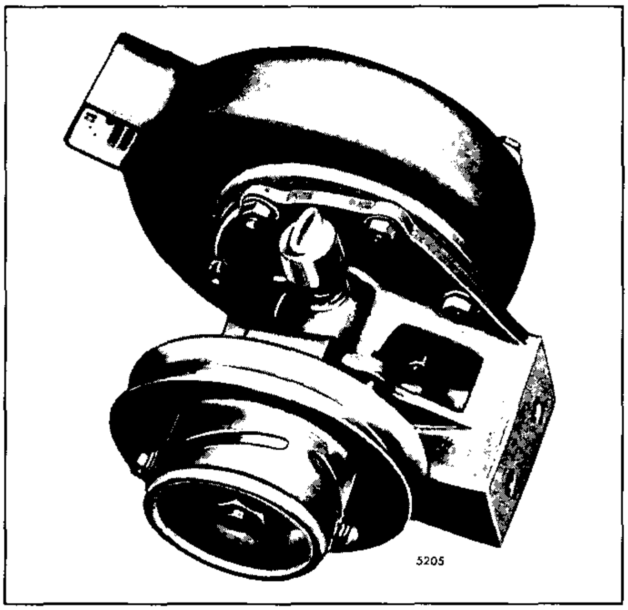


Fig. 1 - Bilge Pump

The bilge pump (Fig. 1) is mounted at the front of the engine and is driven by a V-belt from a pulley on the crankshaft.

The bilge pump runs continuously whenever the engine is operating and is kept in prime by a stream of overflow water from the engine, introduced on the intake side of the pump, through a priming pipe.

The drive shaft is supported on a bronze bushing at the impeller end and a ball bearing to take radial load at the pulley end.

Lubrication

A grease cup provides lubrication for the bronze bushing at the impeller end of the shaft. The cup should be given one-half turn daily, using water-proof grease of the same grade as used on the raw water pump. The ball bearing used at the pulley end of the shaft is grease packed and requires no attention.

A packing gland is provided to adjust the seal on the shaft. Do not tighten it more than necessary to stop leakage. When tightening, draw the nuts down evenly to avoid leaks and scoring of the pump shaft.

Service

Since the bilge pump runs continuously when the engine is operating, the drive belt should be checked at regular intervals. Tension on the belt should be sufficient to avoid slipping, but not great enough to impose an undue load on the pump bearings. Three-fourths inch slack midway between the two pulleys should provide satisfactory operation. Adjustment is accomplished by loosening the adjusting screws at the forward pulley hub and moving the hub in the slot to obtain suitable slack. In freezing weather, open the drain cock to empty the pump if the engine is to be standing idle for any length of time.

Remove And Install Pump

The bilge pump may be removed from the engine by removing the four bolts which attach the mounting bracket to the engine.

The pump is simple in construction and may be disassembled for inspection and reassembled without special instructions. Since the pump priming pipe is permanently connected to the pump as installed on the engine, no special precautions are required for installation other than to make correct connections to the inlet and outlet sides.

All piping on the intake side of the bilge pump must be air tight. Use pipe joint compound on the pipe threads at all connections.

VACUUM PUMP

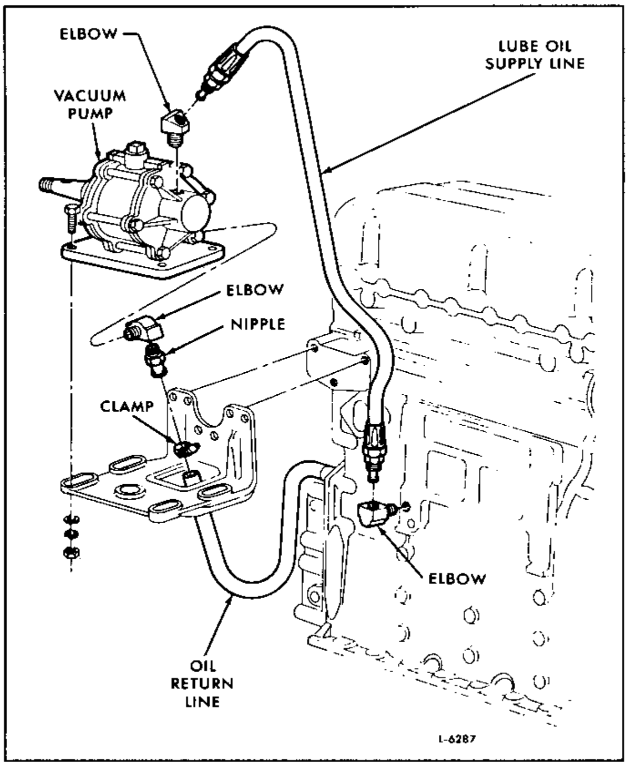


Fig. 1 – Vacuum Pump Installation

Installing A Vacuum Pump

When a former style vacuum pump is replaced with a current design pump, the location of the lube oil supply line on the new pump will differ from that on the replaced pump.

Former vacuum pumps had the oil supply line routed to a threaded hole on the underside of the support bracket. Pump components were lubricated by means of a drilled passage in the base of the pump body which lined up with the inlet hole in the support bracket.

Current pumps do not have the drilled passage for lubrication. Instead, pump components are lubricated by an oil supply line routed to a threaded hole in the top of the rear cover plate (Fig. 1).

To eliminate the possibility of internal vacuum pump damage caused by improper lube oil line hookup, follow this procedure when installing a new pump.:

1. Mount the new pump securely on the support bracket. Make sure the support bracket is properly bolted to the engine.
2. Locate the threaded hole in the pump rear cover plate (opposite the pulley end) and remove the plastic shipping plug.
3. Connect the oil supply line to the pump at the threaded hole. Apply 3M EC No. 971 Pipe Sealant (or equivalent) to the male threads of all fittings before installing them in the vacuum pump. Do not apply sealant to the inside diameter of any holes.

Connecting the oil supply line at the threaded hole on the underside of current pumps will result in no lubrication going to the pump. Operation of the pump without lubrication will cause severe damage to the bearing and shaft assembly.

CAUTION: Loss of vacuum caused by internal damage to the vacuum pump may create a potential safety hazard for driver and passengers by lessening vehicle braking force, thus increasing the possibility of accident.

Vacuum pumps are sold by Detroit Diesel Distributors only as assemblies. For component parts contact a Bendix Products Service outlet or Bendix Products Division, South Bend, Indiana.

AIR COMPRESSOR

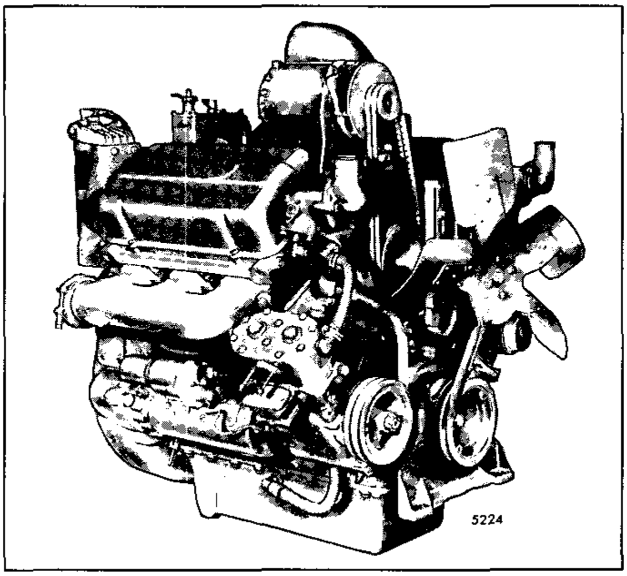


Fig. 1 – Air Compressor Mounting (Former Engines)

The air compressor (Figs. 1 and 2) may be mounted on a bracket atttached to the cylinder block of the engine and belt–driven from the crankshaft pulley, or it may be flange–mounted to the flywheel housing and gear driven by means of an accessory drive attached to the camshaft or balance shaft gear on In–line engines, or on either camshaft gear on V–engines.

A six bolt design air compressor mounting base, mounting bracket and gasket are used on current engines equipped with a belt–driven air compressor. Formerly, the air compressor was attached to the base and bracket with four bolts. When installing a new air compressor, it is recommended that the new mounting parts be used to eliminate the possibility of the bracket loosening and causing oil seepage at the gasket.

The air compressor runs continuously while the engine is running. While the compressor is running, actual compression of air is controlled by the compressor governor which acts in conjuction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the down stroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve and then allows air drawn from the air box in the engine cylinder block or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir.

As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder and the same cycle is repeated.

When the air pressure in the reservoir reaches the maximum setting of the governor, compressed air from the reservoir passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. The air pressure lifts the unloading pistons which in turn lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each upstroke of the piston is merely passed back through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir drops to the minimum setting of the governor, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the piston down and the inlet valve springs return the inlet valves to their seats and compression is resumed.

Service Note

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 3), it is important the 3/4″–16 drive shaft slotted nut be tightened to 100 lb–ft (136 N·m) torque minimum before installing the 3/32″ x 1–1/4″ cotter pin.

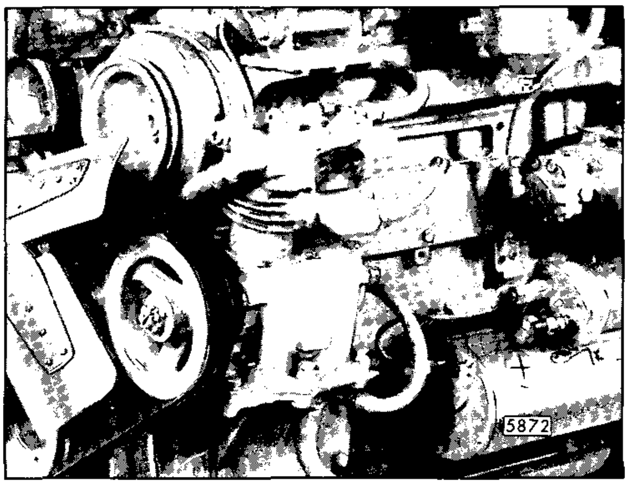


Fig. 2 – Air Compressor Mounting (Current Engines)

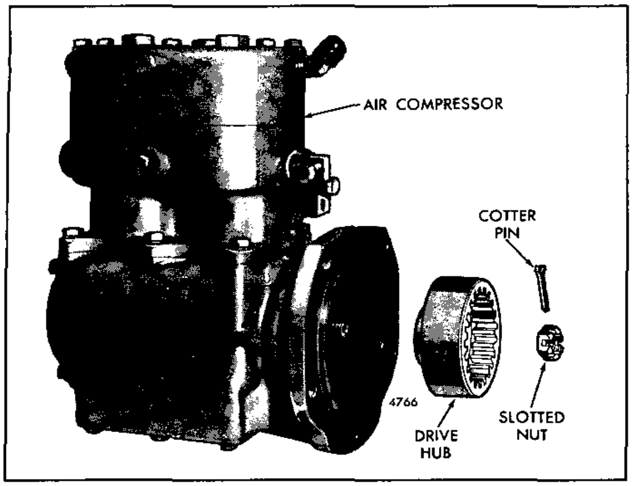


Fig. 3 – Typical Air Compressor with Drive Hub

The air compressor drive shaft will turn during the torquing operation unless some provision is made to hold it. One way this can be done is to weld a modified drive coupling to a support or base which in turn can be anchored to the mounting flange of the compressor. An old flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. With the exterior splines of the coupling in mesh with the internal splines of the drive hub and the entire assembly secured to the compressor housing, the hub and shaft are kept from rotating when the torque is applied. That part of the base within the inner diameter of the coupling must be removed to permit placement of the wrench socket on the nut. Two bolts will secure the base to the compressor during the torquing operation (Fig. 4).

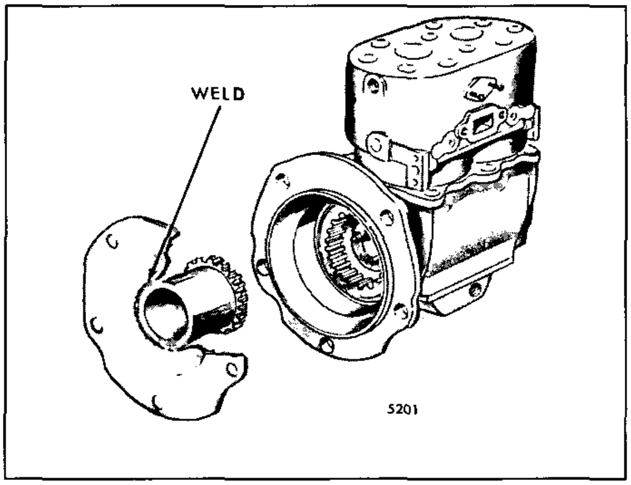


Fig. 4 – Fixture for Holding Drive While Installing or Removing Slotted Nut

COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls, cooling water and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort required to crank the engine is much greater than when the engine is warm.

In a diesel engine, the normal means of igniting the fuel sprayed into the combustion chamber is by the heat of the air compressed in the cylinder. This temperature is high enough to ignite the fuel under ordinary conditions, but at extremely low outside temperatures may not be sufficiently high enough to ignite the fuel injected.

To assist in starting an engine under low temperature conditions, cold weather starting devices are available.

Starting aids are not intended to correct other deficiencies such as low battery, heavy oil, etc. They are for use when other conditions are normal but the air temperature is too low for the heat of compression to ignite the fuel/air mixture.

PRESSURIZED CYLINDER STARTING AID

OPERATION

Start the engine during cold weather, using the "Quick Start" starting aid system (Fig. 1) as follows:

1. Press the engine starter button.
2. Pull out the "Quick Start" knob for one or two seconds, then release it.
3. Repeat the procedure if the engine does not start on the first attempt.

   NOTICE: To avoid starter damage, do not crank the engine more than 30 seconds at a time when using an electric starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

SERVICE

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.
2. Lubricate the actuator cable.
3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.
4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.

   CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

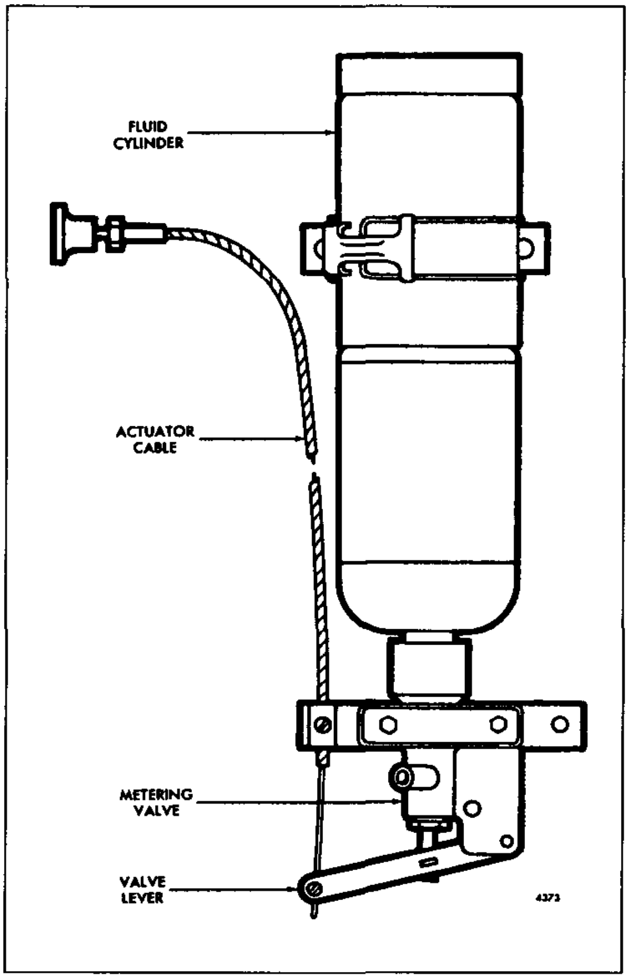


Fig. 1 – Quick Start Assembly

5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.

6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and retighten the air inlet housing fitting to the housing.

CAUTION: Do not actuate the starting aid more than once with the engine stopped. Over-loading the engine air box with this highly volatile fluid could result in a minor explosion, engine damage, and possible personal injury.

7. Check the fluid cylinder for hand tightness.

FLUID STARTING AID

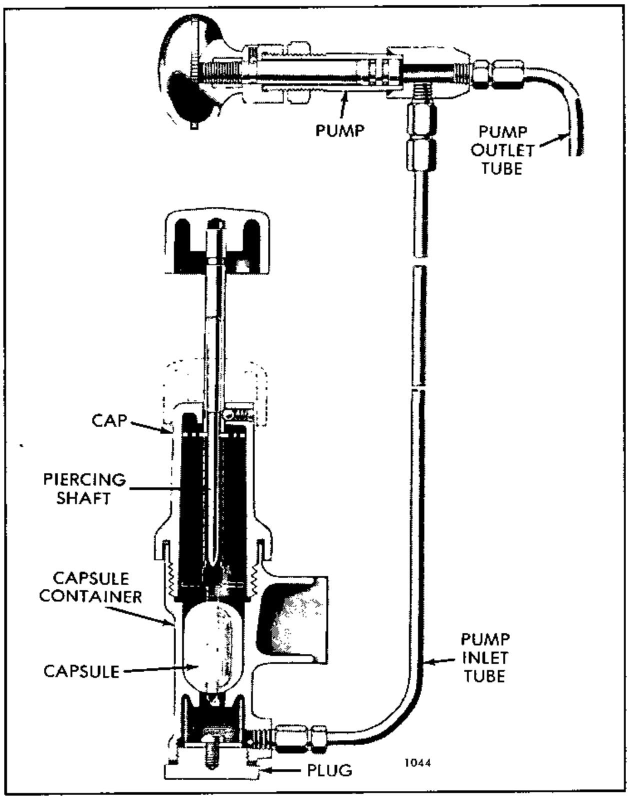


Fig. 2 – Fluid Starting Aid

The fluid starting aid is designed to inject a highly volatile fluid into the air intake system to assist ignition of the fuel at low ambient temperatures. It consists essentially of a pump and nozzle for injecting the fluid into the air intake, and a suitable container for the fluid (Fig. 2). The fluid is contained in suitable capsules to facilitate handling.

This starting aid consists of a cylindrical capsule container fitted with a screw cap. Inside the container is a sliding plunger–like piercing shaft. From the capsule container a tube leads from the container to a hand–operated pump and another tube leads from the pump to an atomizing nozzle threaded into a tapped hole in the air inlet housing.

INSTALLATION

The pump may be mounted on the instrument panel or in some other convenient location. The capsule container must be mounted in a vertical position away from such high heat areas as the exhaust manifold, muffler, etc. and should be located under a hood or in a cab. The atomizing nozzle is screwed into a tapped hole in the air inlet housing. The tank–to–pump tube should be 3/16" O.D. copper tubing and the pump–to–nozzle tube 1/8" O.D.

OPERATION

1. Refer to Fig. 2 and remove the cap from the capsule container. Insert a fluid capsule in the container.

CAUTION: Mount the capsule in an upright position within the container. Use care when handling, since the starting fluid is highly flammable, toxic, and possesses sleep–inducing properties.

2. Pull the piercing shaft all the way out and thread the cap tight on the container.

3. Push the piercing shaft down until it bottoms. This will break the capsule and fill the container with starting fluid vapor.

4. Move the engine throttle to the full–fuel position.

5. Engage the starter and simultaneously pull the pump plunger all the way out. Then push the plunger in *slowly*, forcing the starting fluid through the atomizing nozzle and into the air intake. Continue to push the pump plunger in until the engine starts. If the plunger is not all the way in when the engine starts, push it in *very slowly* until it locks in the *in* position.

6. Unscrew the cap and remove the used capsule. *Do not leave the empty capsule in the container.*

7. Reinstall the cap tightly on the container body. When not in use, the piercing shaft should be all the way down.

Starting Aid Pump

The principal parts of the starting aid pump are the body, plunger and the spring–loaded ball type inlet and outlet check valves (Fig. 2). The pump body is threaded externally at one end for mounting purposes. One end of the plunger is threaded into the operating knob. Two seal rings of oil resistant material are located in grooves at the other end of the plunger. The inlet check valve, which opens on the suction stroke of the plunger and seats under pressure, is located in the side opening of the pump body. The outlet check valve, which seats under suction and opens under pressure, is installed in the end opening of the pump body. The check valves are identified by the number "1/2" stamped on the inlet valve and the number "30" on the outlet valve. An arrow indicating the direction of flow is also stamped on each check valve.

Remove Pump

Remove the starting aid pump from the mounting panel as follows:

1. Disconnect the starting fluid inlet and outlet tubes from the pump.
2. Unscrew the plunger nut from the pump body and withdraw the plunger assembly.
3. Loosen the pump body jam nut behind the mounting panel.
4. Remove the pump body from the rear of the panel.
5. Remove the jam nut from the pump body.

Disassemble Pump

When the pump was removed from its mounting panel, the plunger assembly was removed from the pump body. If further disassembly is required, proceed as follows:

1. Unscrew the knob from the plunger assembly.
2. Slide the plunger nut from the plunger.
3. The plunger lock ball and spring may be removed by tapping the plunger nut to dislodge them. It is not necessary to remove the plug.
4. Remove the inlet and outlet check valves.

Inspection

Clean the parts with fuel oil and dry them with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Examine the seal rings for wear or cracks. Replace the seal rings if necessary. The check valves cannot be disassembled. However, they may be cleaned by forcing fuel oil through them with any suitable pump. Inoperative valves must be replaced. If excessive resistance was encountered during operation of the pump, the nozzle in the air inlet housing may be plugged. Remove and clean the nozzle.

Assemble Pump

1. Install new seal rings on the plunger.
2. Install the lock spring in the plunger nut. Then place the steel ball on top of the spring.
3. Depress the lock ball and slide the plunger nut — hex end first — over the threaded end of the plunger.
4. Thread the knob on the plunger.
5. Install the outlet check valve (marked "30") in the end opening of the pump body. The arrow must point away from the pump body.
6. Install the inlet check valve (marked "1/2") in the side opening of the pump body. The arrow must point toward the pump body.

Install Pump

1. Thread the jam nut on the pump body.
2. Insert the thread end of the pump body through the mounting panel (from the rear of the panel).
3. Lubricate the seal rings and carefully slide the plunger assembly into the pump body. Thread the plunger nut on the end of the pump body and tighten it.
4. Install the starting fluid inlet and outlet tubes.
5. If removed, install the nozzle in the air inlet housing.

HYDROSTARTER SYSTEM

The Hydrostarter system illustrated in (Figs. 1 and 2) is a complete hydraulic system for cranking internal combustion engines. The system is automatically recharged after each engine start, and can be manually recharged in an emergency. The starting potential does not deteriorate during long periods of inactivity and continuous exposure to hot or cold climates has no detrimental effect upon the Hydrostarter system. Also, the Hydrostarter torque for a given pressure remains substantially the same regardless of the ambient temperature.

The Hydrostarter system consists of a reservoir, an engine–driven charging pump, a manually operated pump, a piston type accumulator, a starting motor and connecting hoses and fittings.

Operation

Hydraulic fluid flows by gravity or slight vacuum from the reservoir to either the engine–driven pump inlet or hand pump inlet. The hand pump is used to supply the initial charge or to recharge the system after servicing or overhaul. Fluid discharging from either pump outlet at high pressure flows into the accumulator and is stored at 3250 psi under the pressure of compressed nitrogen gas. When the starter is engaged with the engine flywheel ring gear and the control valve is opened, high pressure fluid is forced out of the accumulator, by the expanding nitrogen gas, and flows into the starting motor which rapidly accelerates the engine to a high cranking speed. The used fluid returns from the starter directly to the reservoir (Fig. 1).

The engine–driven Hydrostarter charging pump runs continuously during engine operation, recharging the accumulator with fluid. When the proper amount of fluid has been returned to the accumulator, a pressure–operated unloading valve in the engine–driven pump opens and returns the pump discharge directly to the reservoir.

System Components

RESERVOIR. The reservoir is a cylindrical steel tank with a fine mesh screen at the outlet. The filler cap contains a filter to prevent dust and dirt from entering the reservoir.

ENGINE–DRIVEN CHARGING PUMP. The engine–driven charging pump is a single piston, positive displacement type and should run at approximately engine speed. It contains ball check valves and an unloading valve operated by the accumulator pressure. Its operation is entirely automatic and will operate in either direction of rotation.

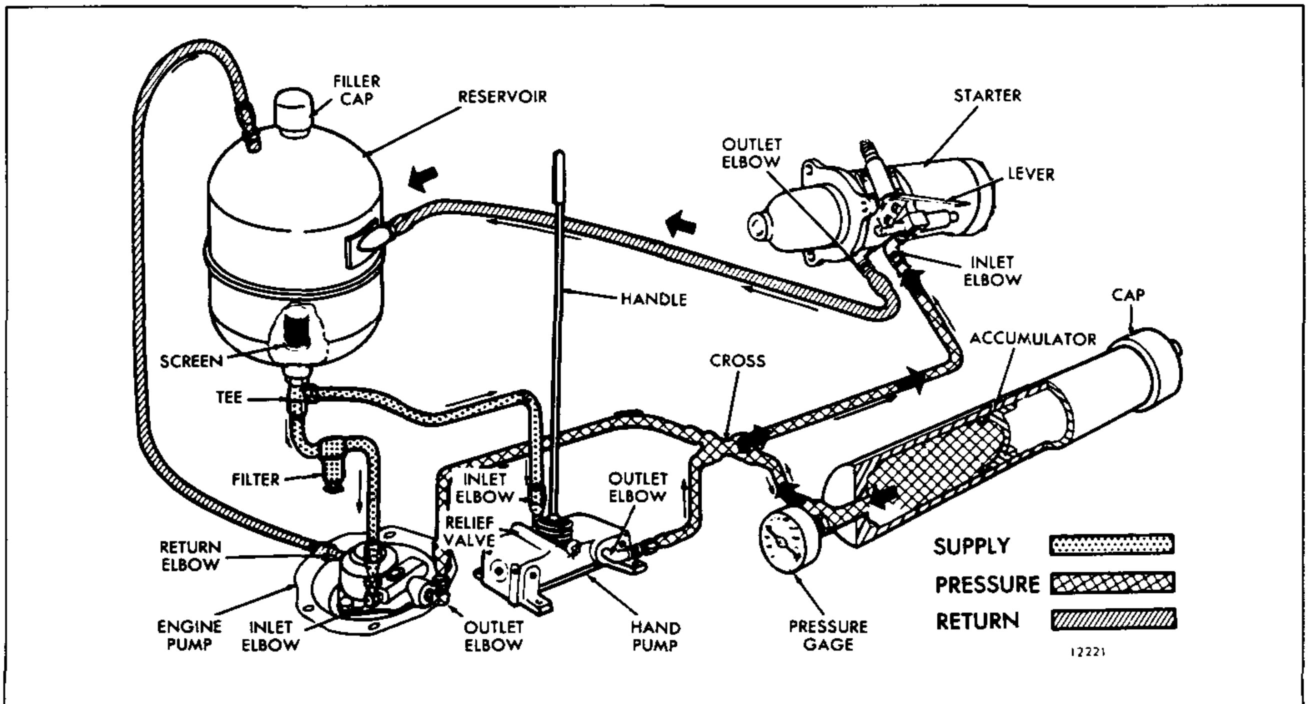


Fig. 1 – Schematic Diagram of Hydrostarter System Showing Oil Flows

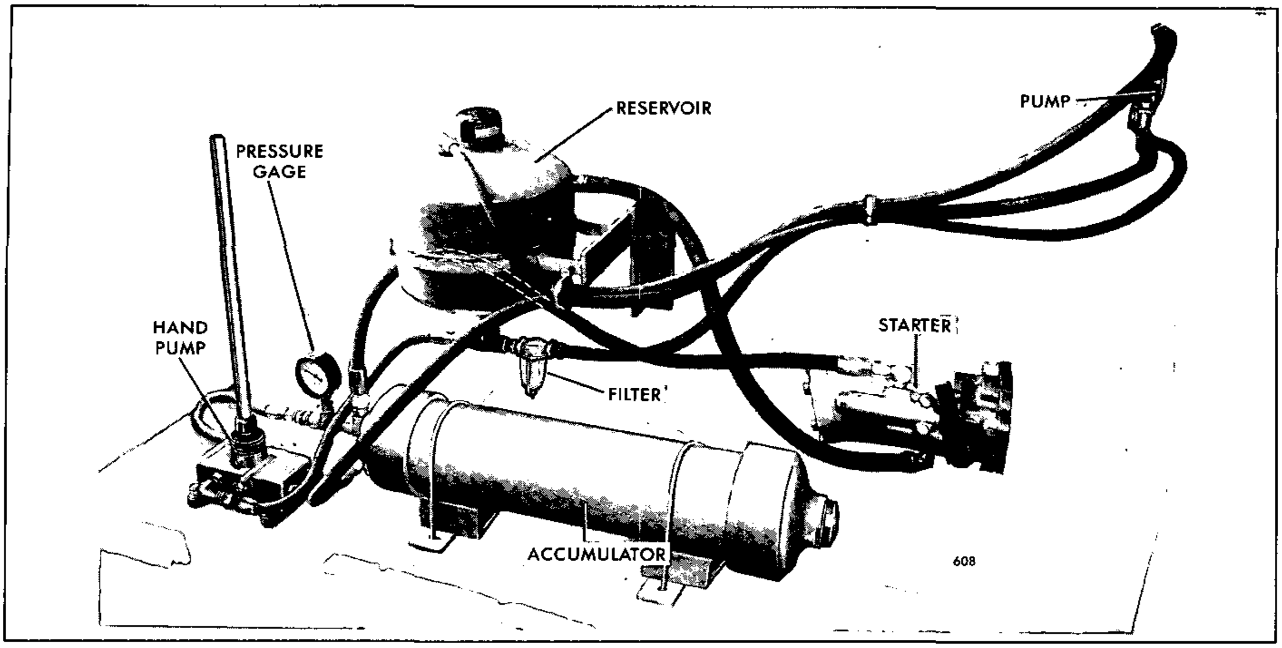


Fig. 2 – Typical Hydrostarter System Mounting

HAND PUMP. The hand pump is a single piston, double–acting, positive displacement type. Flow through the pump is controlled by ball check valves. A manually operated relief valve is provided in this pump so that the accumulator pressure may be relieved when servicing of any components is required.

ACCUMULATOR. The piston–type accumulator is precharged with nitrogen through a small valve. A seal ring between the piston and the shell prevents the loss of gas into the hydraulic system. The accumulator is supplied with the proper precharge.

STARTER. The starter mounts on the flywheel housing and has a pinion gear with an overrunning clutch for engaging the flywheel ring gear. Movement of the starter control lever engages the pinion and opens the control valve in the proper sequence. The motor is a multi–piston, swash plate type. Provision is made so that if pinion tooth abutment occurs, the motor rotates slowly until the pinion snaps into full engagement. When the control lever is released, the pinion is disengaged and the valve is closed by spring action.

Ordering Parts

When ordering replacement parts, always specify the information located by the arrows on each component as shown in (Fig. 3). Also include the engine model and serial number to ensure obtaining the correct parts.

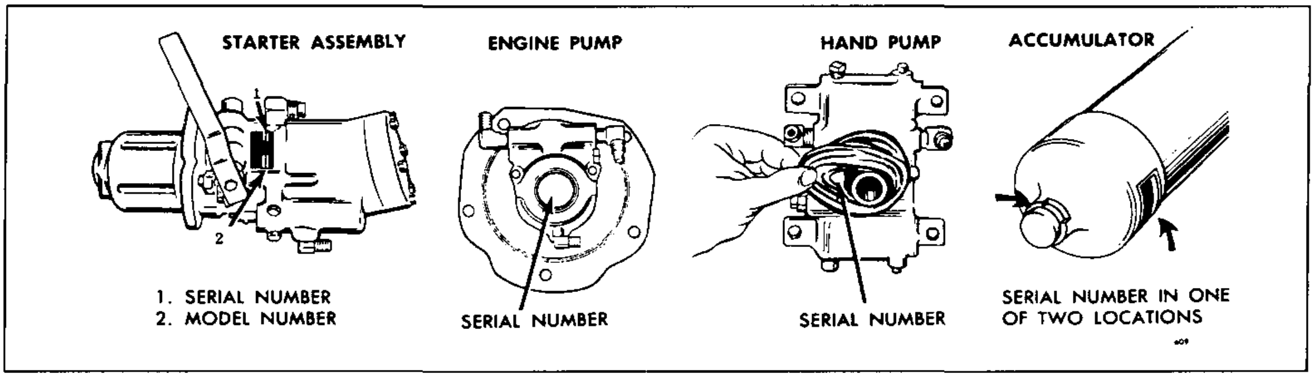


Fig. 3 – Hydrostarter Component Serial Number Locations

FILLING, PURGING AND STARTING

Fill Hydrostarter System

Remove the filler cap from the reservoir and add a sufficient quantity of recommended hydraulic fluid (a mixture of 75% diesel fuel and 25% SAE 10 or 30 lubricating oil) to fill the system.

The required amount of hydraulic fluid will vary depending upon the size of the reservoir, length of the hydraulic hoses and the size and number of accumulators. The reservoir is available in 10, 12, 16 and 23 quart capacities. In a 10 quart capacity reservoir, add approximately 8 quarts of hydraulic fluid; add approximately 10, 14 or 21 quarts of hydraulic fluid to the 12, 16 and 23 quart capacity reservoirs respectively.

When the accumulator is charged to 3000 psi and all hoses are filled, there should be enough hydraulic fluid remaining in the reservoir to completely cover the screen in the bottom of the reservoir.

Purge Hydraulic Remote Control System, Hand Pump and Starter of Air

On units equipped with a hydraulic remote control starting system consisting of a foot pedal, master cylinder and connecting hose and fittings, purge that portion of the Hydrostarter system as follows:

Fill the master cylinder reservoir with diesel fuel oil. Loosen the hose swivel fitting at the back of the starter control valve body and actuate the master cylinder pedal to allow the air to escape from the hydraulic remote starting system. Replenish the fluid in the master cylinder reservoir as required during the purging operation. Then tighten the hose swivel fitting.

Remove the pressure hose (Fig. 1) on the side of the hand pump and pump a few strokes to prime the pump. Priming is complete when a full stream of oil is discharged at each end of the pumping stroke. Then reconnect the pressure hose.

Move the starter control lever (Fig. 4) to engage the starter pinion with the flywheel ring gear and to open the control valve. While holding the lever in this position, operate the hand pump until the starter has turned several revolutions. Then release the starter control lever.

Check Accumulator Precharge Pressure Prior to Initial Engine Start

The precharge pressure of the accumulator is the pressure of the nitrogen gas with which the accumulator is initially charged. This pressure should be checked before the system pressure is raised for the the initial engine start. To check the precharge pressure, open the relief valve (Fig. 1) on the side of the hand pump, approximately 1/2 turn, allowing the pressure gage to return to zero. Close the relief valve and pump several strokes on the hand pump. The gage should show a rapid pressure rise from zero to the nitrogen precharge pressure, where it will remain without change for several additional strokes of the pump.

Initial Engine Start

Use the hand pump (Fig. 1) to raise the accumulator pressure until the gage reads as indicated in the following chart.

Ambient Temperature	Pressure Gage Reading
Above 40°F.	1500 psi
+40°F. to 0°F.	2500 psi
Below 0°F.	3300 psi

Use the priming pump (Fig. 24) to make sure the fuel filter, fuel lines and injectors are full of fuel before attempting to start the engine.

For ambient temperatures below 45°F., use a fluid starting aid.

Add starting fluid just prior to moving the Hydrostarter lever and during the cranking cycle as required. Do not wait to add the starting fluid after the engine is turning over because the accumulator charge may be used up before the engine starts. In this case, the accumulator charge must be replaced with the hand pump.

With the engine controls set for start (throttle at least half–open), push the control lever (Fig. 4) to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve quickly when the engine fires to conserve the oil pressure in the accumulator and to prevent excessive overrunning of the starter drive clutch assembly.

Three different basic types of flywheel ring gears are used — no chamfer, Bendix chamfer and Dyer chamfer on the gear teeth. Some difficulty may be encountered in engaging the starter pinion with the Dyer chamfered ring gears. When this happens, it is necessary to disengage and re–engage until the starter pinion is cammed in the opposite direction enough to allow the teeth to mesh.

Purge Engine–Driven Pump of Air

With the engine running at 1500 rpm or above, loosen the hose connection at the discharge side of the engine–driven pump until a full stream of oil is discharged from the pump. Connect the hose to the pump and alternately loosen and tighten the swivel fitting on the discharge hose until the oil leaking out when the fitting is loose appears free of air bubbles. Tighten the fitting securely and observe the pressure gage. The pressure should rise rapidly to the accumulator precharge pressure (1250 psi at 70°F.) then increase slowly to 2900 to 3300 psi in 6 to 10 minutes, depending upon the size of the particular accumulator.

If the accumulator pressure does not rise, make certain the relief valve (Fig. 1) is closed after the pressure is released and repeat the above purging procedure.

Engine–Driven Pump By–Pass Check

The engine–driven pump should by–pass oil to the reservoir when the pressure reaches 2900 to 3300 psi. Check to determine that the pump is by–passing by removing the reservoir filler cap and disconnecting the pump by–pass hose at the reservoir and holding the hose over the open reservoir filler spout. An occasional spurt of oil may emit from the hose prior to by–passing. When the pump by–passes, a full and continuous stream of oil will flow from the hose. Reconnect the hose at the reservoir and install the filler cap.

HYDROSTARTER MOTOR

The Hydrostarter (starting) motor is mounted on the flywheel housing in the same manner as a conventional starting motor. This starting motor has an inherently high rate of acceleration; therefore, the engine is cranked faster than is possible with other starting systems. Right and left–hand starters are achieved by assembling the motor housing (Fig. 4) to the valve plate in one of two positions 180° apart and by changing the drive clutch assembly. The drive housing can be adjusted in 12 different positions to accommodate various flywheel housing configurations.

The control lever may be attached in any one of four positions where it is most accessible.

Positive starting motor engagement is assured because movement of the control lever mechanically pushes the starter pinion into engagement with the engine flywheel ring gear before the control valve is fully opened. When a tooth abutment is encountered, the valve permits a small flow of oil to turn the pinion slowly until it snaps into full engagement. Spring action disengages the pinion and closes the control valve when the lever is released. An overrunning clutch protects the starting motor at all times from being driven at high speeds by the engine before disengagement of the pinion.

Remove Hydrostarter Motor

1. Release the oil pressure in the hoses and the accumulator by opening the relief valve (Fig. 1) on the side of the hand pump.

   CAUTION: The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other parts to prevent possible injury to personnel or equipment damage.

2. Clean all of the exterior dirt from the Hydrostarter and the hydraulic hoses.
3. Disconnect the remote control hose or linkage, if used.
4. Disconnect the two hydraulic hoses from the starting motor. Cover the open ends of the hoses with masking tape to prevent the entry of dirt.
5. Remove the three bolts and lock washers and lift the starting motor away from the flywheel housing.

Disassemble Hydrostarter Motor

With the exterior of the Hydrostarter motor cleaned, scribe marks on the drive housing, clutch housing, valve plate and motor housing prior to disassembly to ensure their correct reassembly. Refer to (Figs. 4 and 6) and proceed as follows:

1. Remove the two bolts and lock washers and lift the control valve assembly from the valve plate. Remove the body seal ring from the valve plate.
2. Withdraw the control valve from the valve body.
3. Remove the control valve plug only if the control valve body seals are to be replaced. If necessary, remove the valve seal rings from the valve body, being careful not to scratch or damage the valve body.
4. Remove the four bolts and lock washers and slide the drive housing off the shaft. Remove the plug and the oil wick from the drive housing.
5. Remove the four bolts and lock washers and separate the clutch housing and the clutch assembly from the valve plate by sliding them off the shaft. Rotate the control shaft and disengage the overrunning clutch from the fork.
6. Lift the clutch yoke from the drive clutch assembly. Remove the fork from the control shaft.

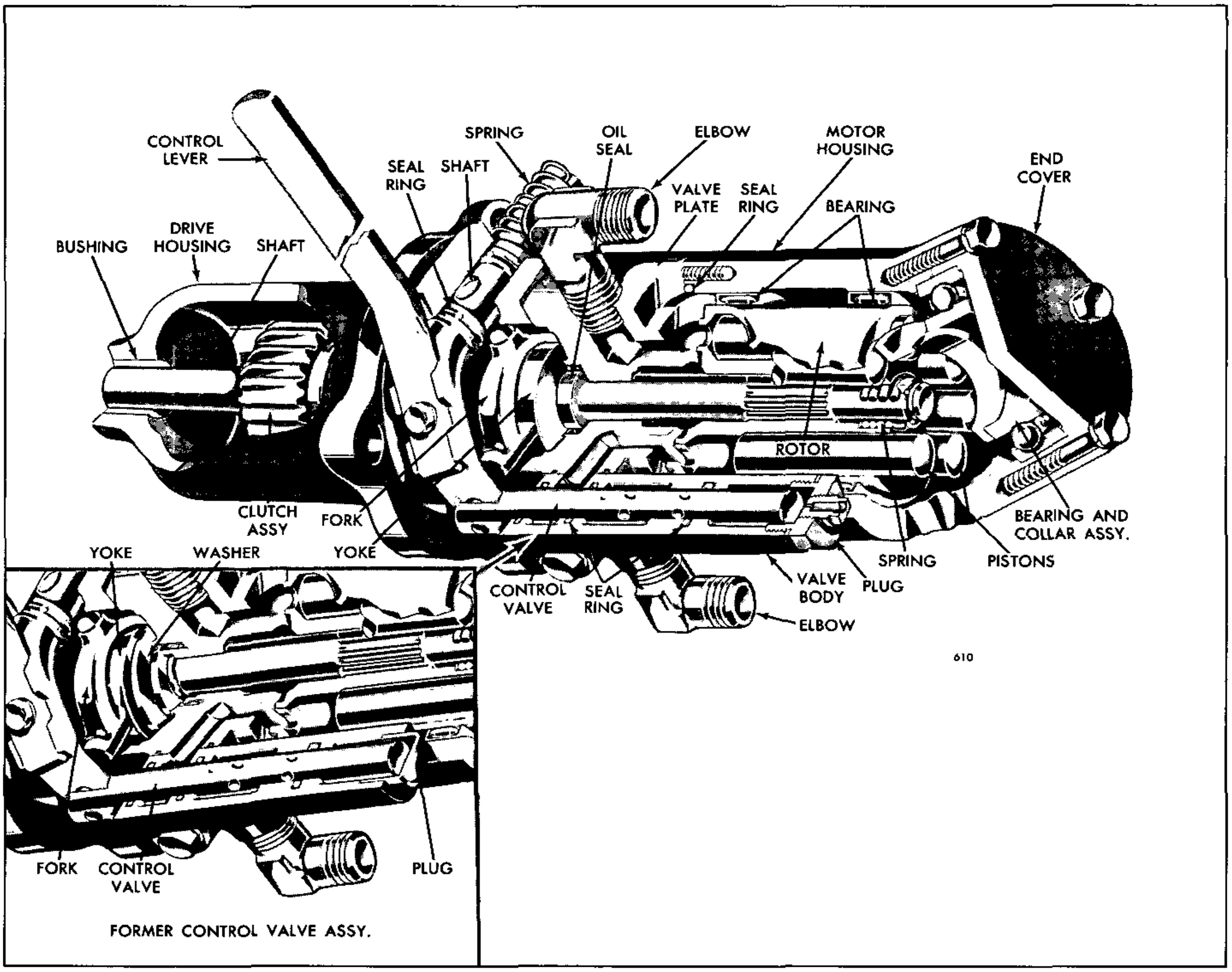


Fig. 4 – Cutaway View of Hydrostarter

7. Remove the torsion spring from the control shaft and pull the shaft from the clutch housing. Remove the seal rings from the control shaft. Remove the control lever only if broken or if its position on the control shaft is to be changed.

8. On a Series "20" Hydrostarter motor equipped with the former control valve assembly, shown in the inset in (Fig. 4), remove the drive shaft oil seal washer from the starter shaft.

9. Withdraw the motor housing and needle bearing assembly together with the end cover and bearing as an assembly from the valve plate, being careful not to drop the pistons from the rotor.

10. Remove the pistons from the rotor.

11. Locate the shaft in an arbor press and, using spring compressor J 7187, press on the edge of the retainer to compress the spring as shown in (Fig. 5). Then remove the snap ring.

12. Remove the retainer and compression spring from the starter shaft. Then slide the rotor and the valve plate assembly off of the starter shaft.

13. On a Series "20" motor, remove the starter shaft compression spring shim(s), if used, from the spring bore in the rotor.

On a Series "35" motor, remove the starter shaft compression spring special washer from the spring bore in the rotor.

14. Remove the starter shaft oil seal from the valve plate only if it is leaking.

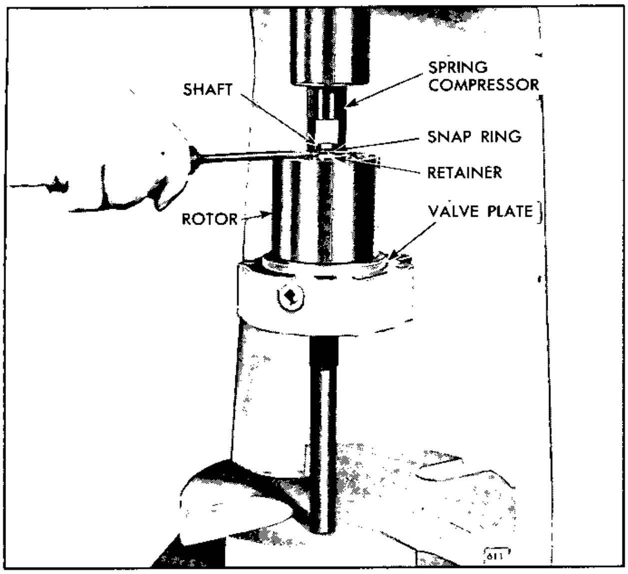


Fig. 5 – Removing Snap Ring from Starter Shaft

15. Remove the seal ring from the motor housing.

16. Remove the bolts and lock washers and separate the end cover, bearing and gasket as an assembly from the motor housing.

17. Remove the bearing and collar assembly ("20" series motor) or the bearing assembly ("35" Series motor) from the end cover.

Inspect Hydrostarter Motor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, with the exception of the drive clutch assembly.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Examine the teeth and internal splines of the drive clutch assembly for excessive wear and replace if necessary.

If the overrunning clutch slips, preventing positive pinion engagement, replace it unless the slippage is due to extremely cold weather which would cause the grease to set up and prevent the clutch from operating. Then wash it thoroughly in clean fuel oil to free the rollers in the clutch shell and lubricate with SAE 5W oil. Attach a tag to the starter, noting the lubricant used in the clutch assembly.

When replacing the drive clutch assembly, only the Delco Remy drive clutch assemblies are available for service and, if the unit did not incorporate a Delco Remy drive clutch before, it will be necessary to replace the drive housing also.

Check the rotor and pistons for scoring or other damage.

Replace the yoke if it is cracked or worn on the faces near slots.

Replace the clutch fork if the trunnions or machined shank of the fork is bent, or are worn out of alignment.

Replace the starter shaft oil seal if the lip is rough or hard.

The rotor bearings (Fig. 4) should not require replacement; however, if they are worn excessively, a new motor housing and bearing assembly must be installed.

Apply light engine oil to the end bearing. Then hold the inner race and revolve the outer race slowly by hand to check for rough spots.

Replace the control shaft torsion spring or compression spring if either is broken or damaged in any way.

A square section split ring was used with the compression spring retainer on early Hydrostarter motors. The current type retainer is used with a round section snap ring. The drive shaft was revised accordingly. When an early type shaft is replaced, a new spring retainer and snap ring are required.

The current Series "20" Hydrostarter motor incorporates a new design control valve assembly that may be identified by the threaded plug in the end of the valve housing. A tapped hole in the plug is provided for attachment of a flexible hose when a remote control is used, otherwise, a 1/8" – 27 vent plug is installed. A cup plug was pressed in the former valve housing.

The washer between the shaft seal and the clutch yoke (see inset in Fig. 4) is used ONLY in the early Series "20" Hydrostarter motors with the former type control valve. If the Hydrostarter motor is overhauled and a new control valve assembly is installed, remove the washer. However, if the control valve assembly is replaced and the motor is not disassembled, the washer may be left in the motor.

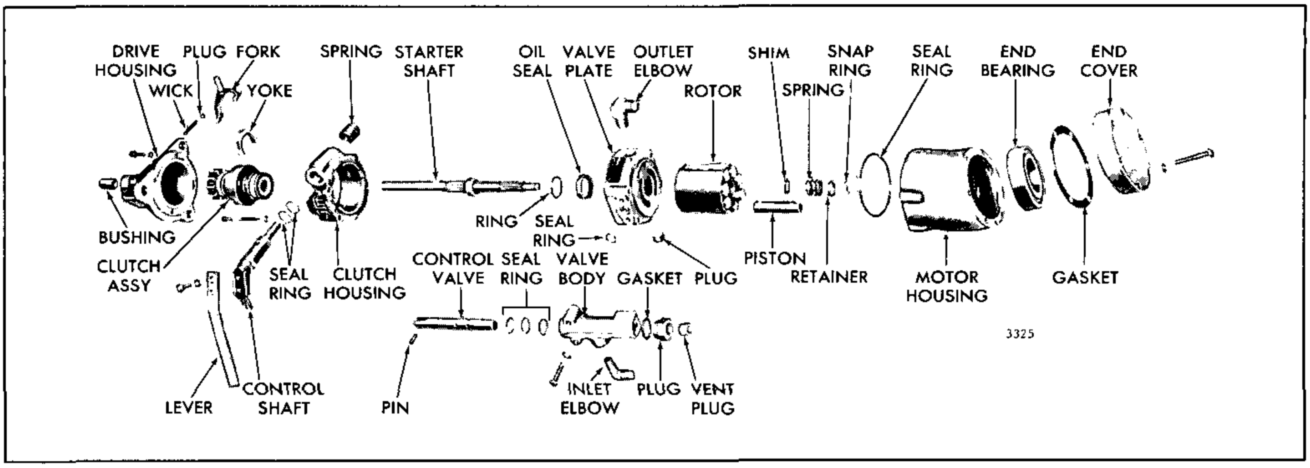


Fig. 6 – Hydrostarter Motor Details and Relative Location of Parts ("20" Series Motor Shown)

Assemble Hydrostarter Motor

Refer to (Figs. 4 and 6) and assemble the Hydrostarter motor as follows:

NOTICE: Do not reassemble a R.H. starter for L.H. rotation. The drive clutch for a R.H. starter will not drive at all if assembled on a L.H. starter. Similarly, the drive clutch for a L.H. starter will not drive if assembled on a R.H. starter. In both of these cases, the clutch will run free and will transmit no torque. The clutch will be forced to run at excessive speeds with a full accumulator and no driving load.

1. On a Series "20" motor, place the bearing and collar assembly in the end cover, thrust collar side up. On a Series "35" motor, place the bearing assembly, numbered end up, in the end cover. Then attach the end cover to the motor housing with bolts and lock washers. Use a new gasket between the cover and the housing.

2. If the shaft oil seal was removed, install a new seal in the valve plate with the lip of the seal facing in, using installer J 7190 on a "20" series motor or installer J 9555 on a "35" series motor (Fig. 7). The seal is properly positioned when the installer bottoms in the valve plate. Install the oil seal retaining ring in the ring groove in the valve plate.

On the former ("20" series motor) valve plate that does not incorporate the shaft oil seal retaining ring groove, stake the seal in place in at least six places.

3. Apply a thin coat of grease on the forward face of the starter shaft collar, then place the valve plate, seal side first, over the forward splined end of the starter shaft, followed by the rotor, shims (if used) on a "20" series motor, a special washer ("35" series motor), compression spring and the spring retainer.

4. With the assembly in an arbor press and using spring compressor J 7187 as shown in (Fig. 5), install the snap ring in the shaft ring groove.

On the current Series "20" Hydrostarter motors, a .031" shim(s) is used on the starter shaft back of the compression spring as shown in (Fig. 8) to limit the starter shaft travel and prevent the collar on the shaft from moving past the lip of the oil seal and damaging the seal when the shaft returns to its normal position. When reassembling a Series "20" Hydrostarter motor, the starter shaft should be checked as shown in (Fig. 9). If the starter shaft travel is more than .100", a .031" shim(s) must be placed back of the compression spring to limit the shaft travel.

5. Insert the pistons, open end first, in the rotor.

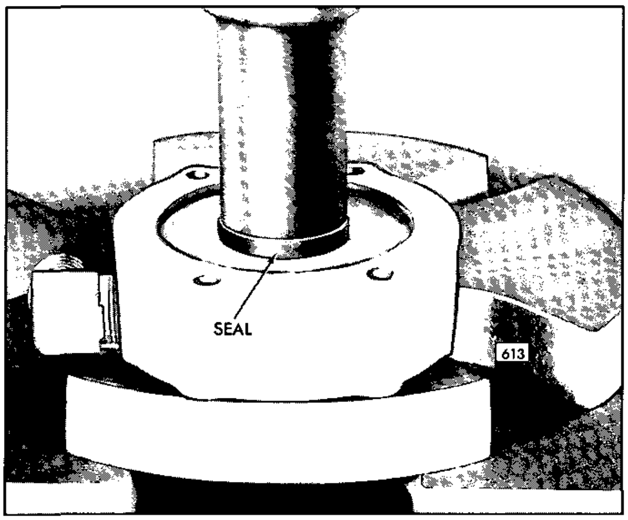


Fig. 7 – Installing Hydrostarter Shaft Seal in Valve Plate

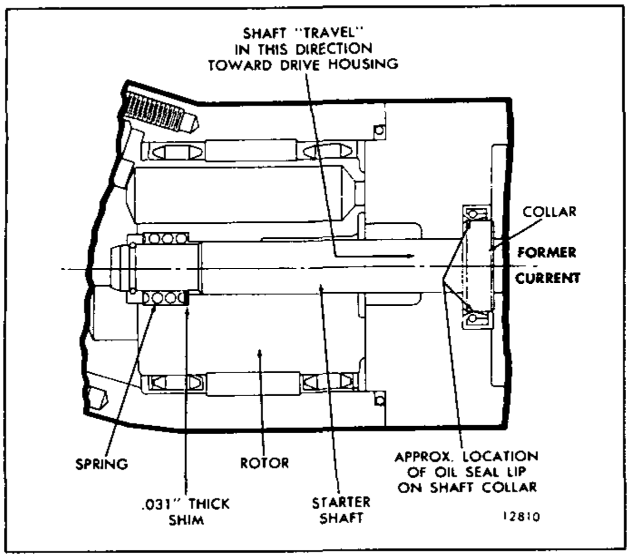


Fig. 8 – Location of Starter Shaft Compression Spring Shim (Series "20" Motor)

6. Install the seal ring on the valve plate. Then assemble the motor housing to the valve plate, noting the scribe marks previously made on the housing and the valve plate.

7. Lubricate and install new seal rings on the control shaft and guide the shaft into the clutch housing gently so as not to damage the seal rings.

8. Install the torsion spring on the end of the control shaft. Apply grease to the fingers of the clutch fork and insert the shank of the fork into the control shaft.

9. Apply grease to the slots of the yoke and to the spool of the drive clutch assembly. Then set the yoke in the collar of the drive clutch assembly.

10. Grease the internal splines in the drive clutch assembly and the external splines on the starter shaft. Rotate the control shaft and insert the clutch fork trunnions into the slots of the yoke. Slide the oil seal washer, if used, onto the shaft. Then slide the assembly, yoke end first, over the starter shaft and engage the clutch and the shaft splines.

    The starter shaft oil seal washer, mentioned in Step 10, is only used on Series "20" Hydrostarter motor assemblies using the former control valve assembly shown in the inset in (Fig. 4).

11. Align the scribe marks and the bolt holes of the motor housing, valve plate and clutch housing and install the attaching bolts and lock washers.

12. Dip the oil wick in engine oil and insert the wick in the drive housing and secure it with the pipe plug.

13. Align the scribe marks on the drive housing and the clutch housing, then secure the drive housing with bolts and lock washers.

14. If removed, install new seal rings in the seal ring grooves inside the control valve body, then install the control valve body plug in the valve body and the vent plug in the body plug.

    On a former (Series "20" motor) control valve body, shown in the inset in (Fig. 4), press the cup plug against the shoulder in the control valve body.

15. Lubricate the control valve with engine oil, then start the control valve, slotted end out, straight in the control valve body and push it through the three seal rings in the body.

16. Place a new seal ring in the counterbore of the valve plate, engage the roll pin in the slot of the control shaft and attach the control valve assembly to the valve plate with bolts and lock washers.

17. If removed, attach the control lever to the control shaft with bolts and lock washers.

Install Hydrostarter Motor

1. Attach the Hydrostarter motor securely to the flywheel housing with three bolts and lock washers.
2. Connect the two hydraulic hoses to the starter.
3. Connect the remote control hose or linkage, if used. Make sure the hoses and fittings are clean before any connections are made.

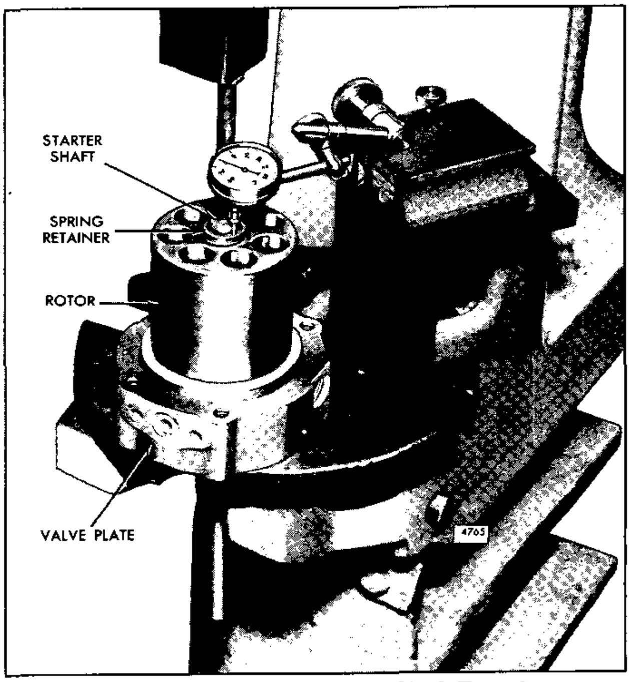


Fig. 9 – Checking Starter Shaft Travel (Series "20" Motor)

ENGINE–DRIVEN HYDROSTARTER CHARGING PUMPS

Depending upon the engine application, either a direct engine–driven charging pump or a belt–driven pump is included in the Hydrostarter system to maintain the proper operating pressure.

The charging pump runs continuously to maintain a pressure of approximately 2900–3300 psi in the accumulator. However, the pump must not be driven at a constant speed exceeding 2500 rpm. An unloading valve, contained within the pump body, by–passes the pump discharge to the reservoir after the operating pressure is attained and, thereafter, permits the pump to operate at less load.

The pump, which will operate in either direction of rotation, will maintain the Hydrostarter system pressure, without appreciable loss, for long periods of time after the engine is shut down.

A sediment bowl is installed in the suction hose to provide the necessary finer degree of filtration required to protect the engine–driven pump mechanism. The sediment bowl encloses a stacked disc type element that may be cleaned and reused.

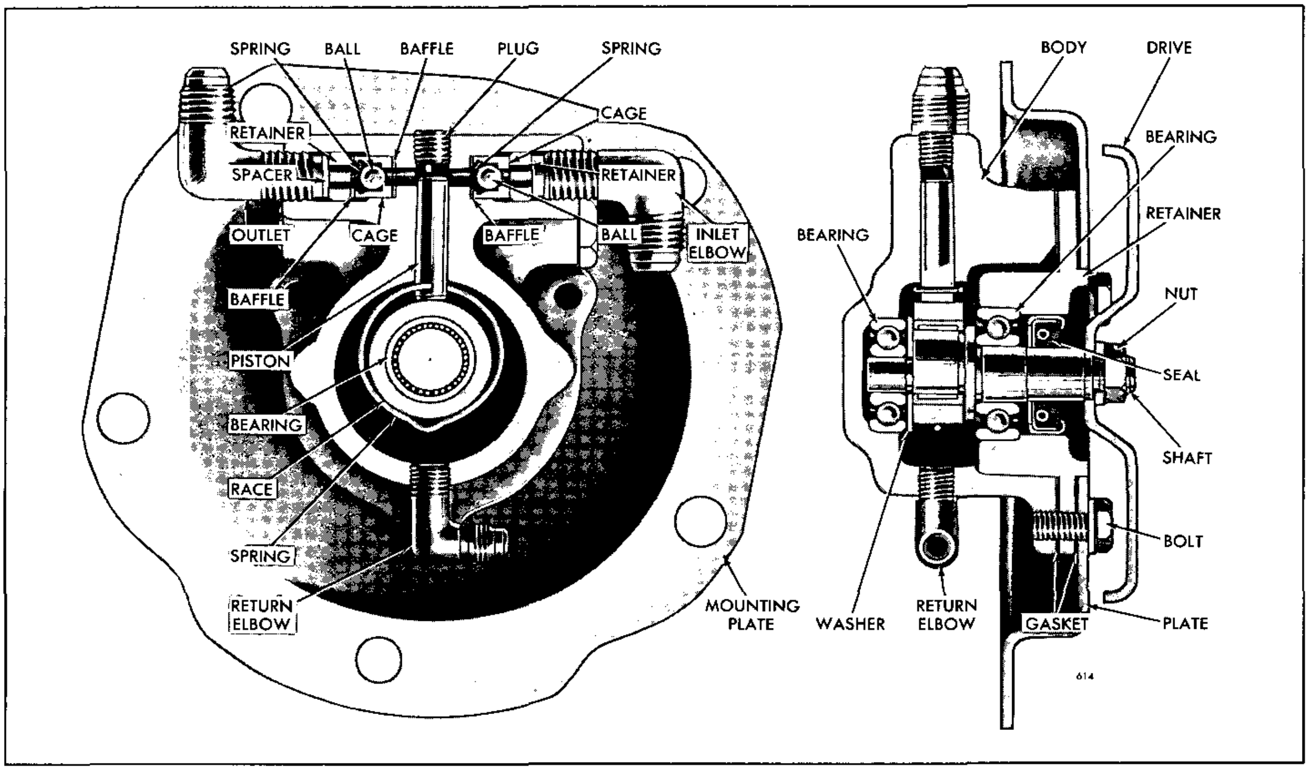


Fig. 10 – Direct Engine–Driven Hydrostarter Charging Pump

DIRECT ENGINE–DRIVEN CHARGING PUMP

The direct engine–driven charging pump (Fig. 10) is a single –piston positive displacement type. The ball check valves and the unloading valve are automatically controlled by the accumulator pressure. The pump shaft is supported on ball bearings and a seal, pressed into the pump bearing retainer, prevents leakage. The pump is attached to the flywheel housing and is driven by a drive plate bolted to the camshaft gear (Fig. 11).

Remove Pump

If required, remove the pump as follows:

1. Release the oil pressure in the system by opening the relief valve (Fig. 1) on the side of the hand pump about 1/2 turn.

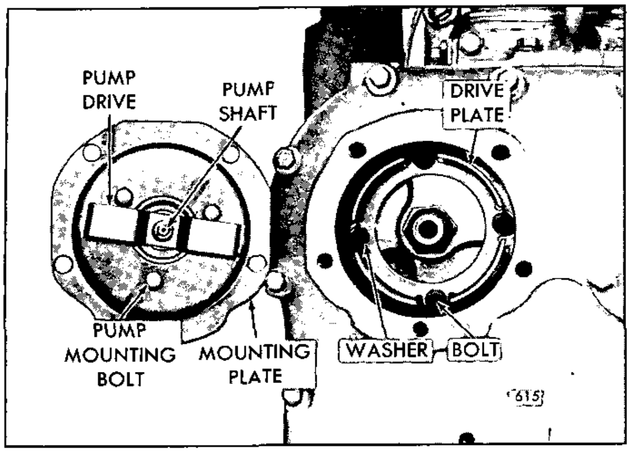


Fig. 11 – Pump Drive Plate Mounting

CAUTION: The oil pressure in the system must be released prior to servicing the pump or other parts to prevent possible injury to personnel or equipment damage.

2. Clean all of the exterior dirt from the pump and the hydraulic hoses.
3. Disconnect the hydraulic hoses from the charging pump. Then cover the open ends of the hoses to prevent the entry of dirt.
4. Remove the five bolts and lock washers securing the charging pump and mounting plate assembly to the flywheel housing (Fig. 11). Then remove the pump and mounting plate assembly. Remove the mounting plate gasket.

Disassemble Pump

With the pump removed from the engine, refer to (Figs. 10 and 12) and proceed as follows:

1. Remove the nut and lock washer and withdraw the pump drive from the shaft.
2. Scribe marks on the mounting plate and the pump body prior to disassembly to ensure their correct reassembly.
3. Remove the three bolts and lock washers and separate the mounting plate from the pump. Remove and discard the gasket. Withdraw the bearing retainer from the pump body. Remove and discard the second gasket.
4. Remove the shaft, bearings and fiber washer as an assembly from the pump body.
5. If inspection reveals the bearings and fiber washer are worn excessively, remove them from the pump shaft for replacement by new parts.
6. Remove the pump piston and the retaining spring from the pump body.
7. Remove the pressure relief spring retaining plug, gasket, spring and spring seat.

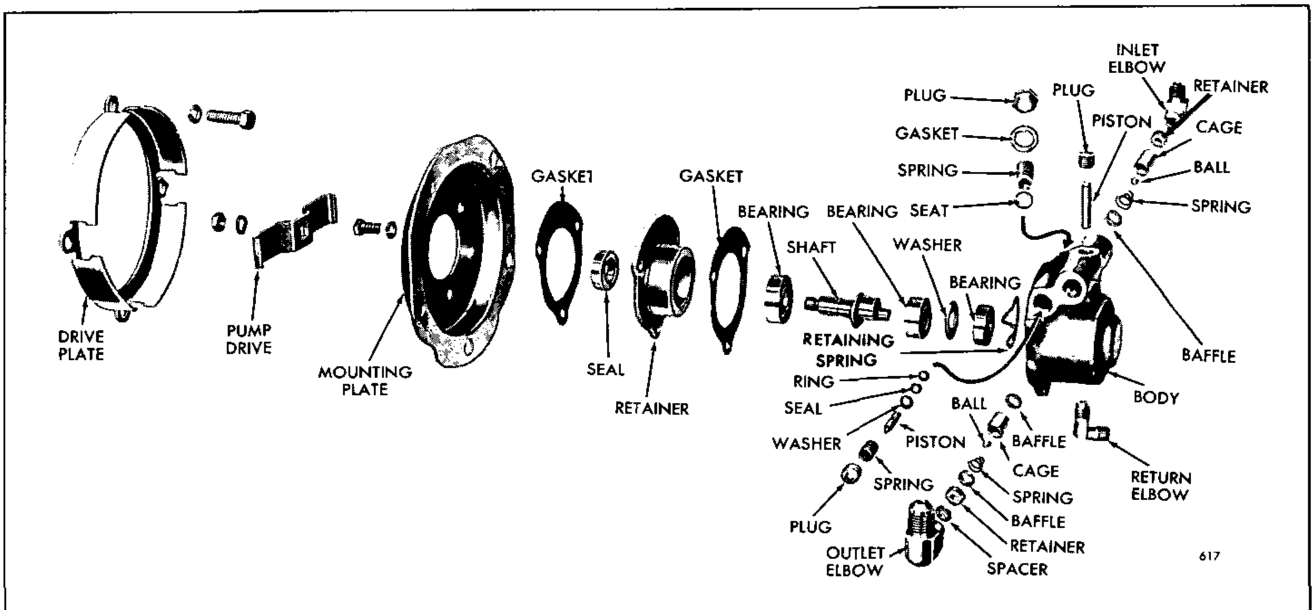


Fig. 12 – Direct Engine–Driven Charging Pump Details and Relative Location of Parts

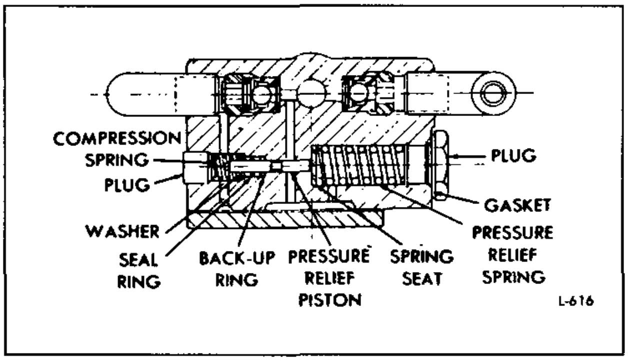


Fig. 13 – Engine-Driven Hydrostarter Charging Pump Pressure Relief Piston Assembly

8. Remove the compression spring retaining plug, compression spring, pressure relief piston, washer, seal ring and back-up ring.

9. Remove the pump outlet elbow, spacer, retainer and baffle.

The helical spring, ball and cage may then be removed as an assembly. Remove the baffle. DO NOT separate the helical spring and ball from the cage. If the check valve on either side of the pump is defective, replace the complete check valve assembly.

10. Remove the pump inlet elbow and the check valve retainer. Then remove the cage, ball and spring as an assembly. Remove the baffle. DO NOT separate the spring and ball from the cage.

11. The pump–to–reservoir return elbow and plug may be removed, if necessary, to clean the pump body.

12. Remove the oil seal from the bearing retainer if the seal is worn or damaged.

Assemble Pump

After cleaning, inspecting and replacing the necessary parts, refer to (Figs. 10 and 12) and proceed as follows:

1. Insert the spring seat and pressure relief spring in the pump body and lock them in place with a gasket and plug.

2. Slide a new back–up ring, new seal ring and washer onto the end of the pressure relief piston, opposite the flat end. DO NOT slide the seal across the groove in the piston.

3. Coat the back–up ring and seal ring liberally with hydraulic fluid. Then insert the relief piston assembly into the pump body, the flat end of the piston first, using installer J 7192. Apply manual force to the installer in order to gradually work the back–up ring and seal ring into the counterbore around the pressure relief piston. Care must be taken to avoid cutting the seal ring as it is worked into place. Refer to (Figs. 13 and 14).

4. Remove the washer and inspect the work to make certain the seal ring is completely in the counterbored hole and that the pressure relief piston is down solidly against the spring seat.

5. Reassemble the washer over the pressure relief piston and insert the compression spring and secure it in place with the plug. Use sealant (Permatex No. 2, or equivalent) sparingly on the threads of the plug.

6. Insert the baffle, check valve assembly (with the spring end facing out) and the baffle into the pump body. Screw the check valve retainer into the body, against the baffle, and tighten it to 120–140 ***lb–in*** torque.

7. Place the spacer in the body on top of the check valve retainer and install the pump outlet elbow, using sealant (Permatex No. 2, or equivalent) on the threads. DO NOT apply sealant on the last thread nearest the open end of the elbow.

8. Insert the baffle and check valve assembly (with the spring end of the assembly in first) into the pump body. Screw the check valve retainer into the pump body against the check valve cage and tighten it to 120–140 ***lb–in*** torque. Install the pump inlet elbow, using sealant (Permatex No. 2, or equivalent) on all of the threads except the last one nearest the open end of the elbow.

9. If the pump–to–reservoir return elbow and plug were removed, apply sealant to all except the first thread on the elbow and plug and reinstall them.

10. Assemble the pump piston and retaining spring in the pump body.

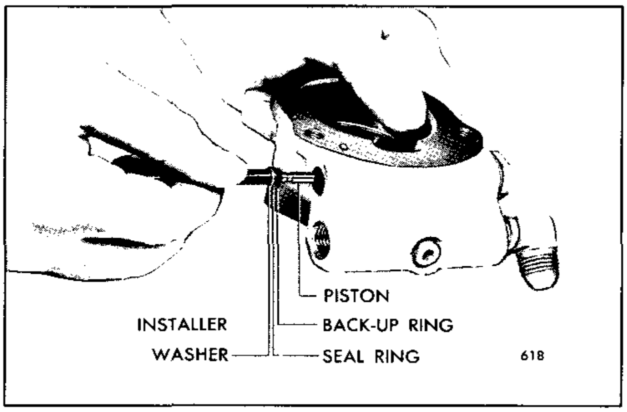


Fig. 14 – Installing Pressure Relief Piston, Back–Up Ring, Seal Ring and Washer in Pump Body with Installer J 7192

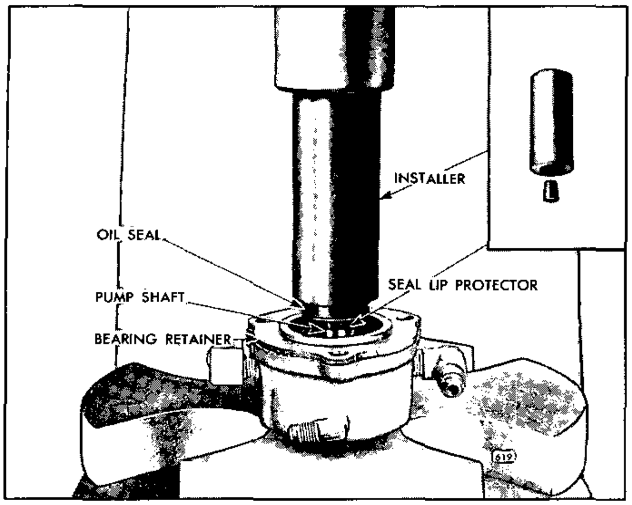


Fig. 15 – Installing Pump Shaft Oil Seal in Bearing Retainer

11. Install the bearing and shaft assembly in the pump body. Work the retaining spring up on the bearing.

12. Affix a new gasket to the pump body and press the bearing retainer by hand into the pump body.

13. Install a new oil seal in the bearing retainer as follows:

    a. Apply a thin coat of sealing compound to the outside diameter of the oil seal casing.

    b. Place the seal lip protector J 7191–3 over the shaft, lubricate the lip of the seal and slide the seal, lip side first, over the seal lip protector and down to the bearing retainer.

    c. Place the seal installer J 7191–1 over the seal lip protector J 7191–3, covering the threaded end of the shaft. Then press the seal in flush with the retainer surface. Refer to (Figs. 10 and 15).

14. Place a second gasket on the bearing retainer. Align the three bolt holes of the mounting plate, bearing retainer, pump body and both gaskets and secure the parts together with bolts and lock washers. Make sure the scribe marks previously made on the mounting plate and the pump body are aligned to ensure proper position of the pump when it is installed on the engine.

15. Secure the pump drive on the shaft with a nut and lock washer.

Install Pump

Refer to (Figs. 2 and 11) and install the pump as follows:

1. Affix a new gasket to the flywheel housing using a non–hardening gasket cement on the flywheel housing side only.

2. Align the tangs on the pump drive with the slots in the drive plate. Attach the pump and mounting plate securely to the engine with bolts and lock washers.

   NOTICE: Do not force the pump into place. Use of force, or tightening the bolts when the mounting flange is not against the flywheel housing, will force the drive arm against the pump body and result in damage to the pump when the engine is started.

3. Connect the hydraulic hoses to the pump.

BELT-DRIVEN CHARGING PUMP

The belt–driven charging pump (Fig. 16) is similar in design and operation to the direct engine–driven pump, but has a longer shaft to accommodate a drive pulley.

Disassemble Pump

With the pump removed from the engine, refer to (Figs. 16 and 17) and proceed as follows:

1. After removing the pulley retaining nut and lock washer, remove the pulley from the shaft, using a suitable puller.

2. Scribe marks on the bearing retainer and pump body prior to disassembly to ensure their correct reassembly.

3. Remove the three retaining bolts and lock washers. Separate the bearing retainer and pump shaft, including the shaft bearings, as an assembly from the pump body. Remove and discard the pump body gasket.

4. Press the pump shaft assembly from the bearing retainer using an arbor press or by tapping on the threaded end of the shaft with a plastic hammer.

5. If inspection reveals the pump shaft bearings and oil seal sleeve are worn excessively, remove them from the pump shaft for replacement by new parts.

6. Remove the needle bearing and outer race, fiber washer, retaining spring, piston and thrust ring from the pump body.

7. Remove the oil seal from the bearing retainer if the seal is worn or damaged.

8. Remove the pressure relief spring retaining plug, gasket, spring and spring seat.

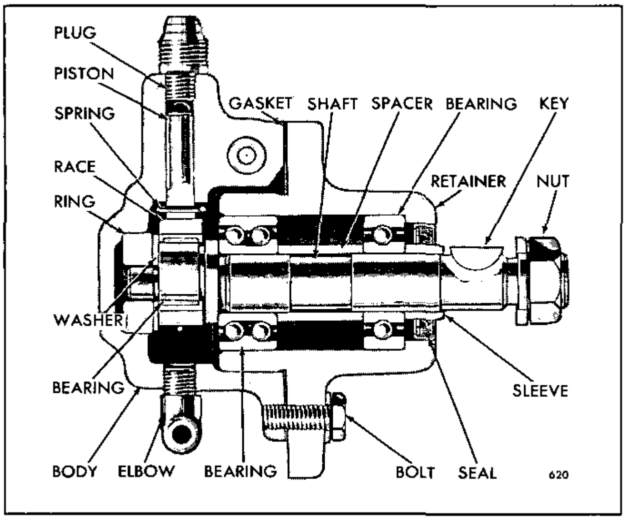


Fig. 16 – Belt-Driven Hydrostarter Charging Pump

9. Remove the compression spring retaining plug, compression spring, pressure relief piston, washer, seal ring and back–up ring.

10. Remove the pump outlet elbow, spacer, retainer and baffle. The helical spring, ball and cage may then be removed as an assembly. Remove the baffle. DO NOT separate the helical spring and ball from the cage. If the check valve on either side of the pump is defective, replace the complete check valve assembly.

11. Remove the pump inlet elbow and the check valve retainer. Then remove the cage, ball and spring as an assembly. Remove the baffle. DO NOT separate the spring and ball from the cage.

12. The pump–to–reservoir return elbow and plug may be removed, if necessary, to clean the pump body.

Assemble Pump

After cleaning, inspection and replacing the necessary parts, refer to (Figs. 16 and 17) and proceed as follows:

1. Insert the spring seat and pressure relief spring in the pump body and lock them in place with a gasket and plug.

2. Slide a new back–up ring, new seal ring and washer onto the end of the pressure relief piston, opposite the flat end. DO NOT slide the seal across the groove in the piston.

3. Coat the back–up ring and seal ring liberally with hydraulic fluid. Then insert the relief piston assembly into the pump body, the flat end of the piston first, using installer J 7192. Apply manual force to the installer in order to gradually work the back–up ring and seal ring into the counterbore around the pressure relief piston. Care must be taken to avoid cutting the seal ring as it is worked into place. Refer to (Figs. 13 and 14).

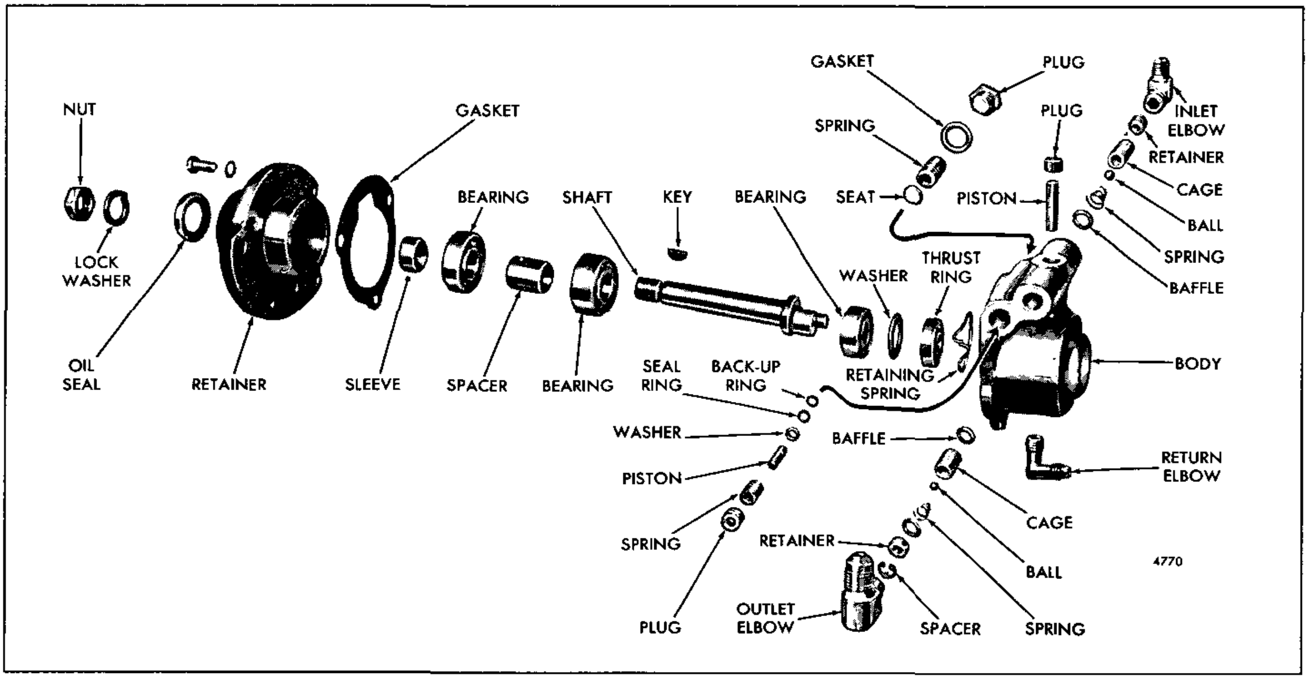


Fig. 17 – Belt-Driven Charging Pump Details and Relative Location of Parts

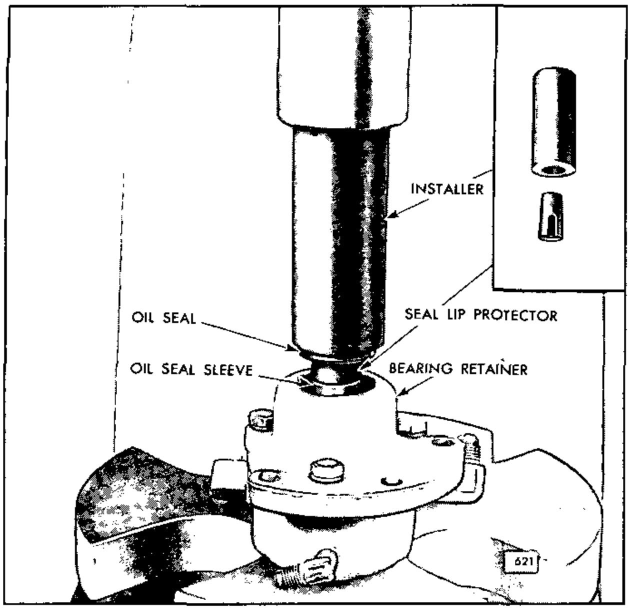


Fig. 18 – Installing Pump Shaft Oil Seal in Bearing Retainer

4. Remove the washer and inspect the work to make certain the seal ring is completely in the counterbored hole and that the pressure relief piston is down solidly against the spring seat.

5. Reassemble the washer over the pressure relief piston and insert the compression spring and secure it in place with the plug. Use sealant (Permatex No. 2, or equivalent) sparingly on the threads of the plug.

6. Insert the baffle, check valve assembly (with the spring end facing out) and baffle into the pump body. Screw the check valve retainer into the body, against the baffle, and tighten it to 120–140 ***lb–in*** torque.

7. Place the spacer in the pump body on top of the retainer and install the pump outlet elbow, using sealant (Permatex No. 2, or equivalent) on the threads. DO NOT apply sealant on the last thread nearest the open end of the elbow.

8. Insert the baffle and check valve assembly (with the spring end of the assembly in first) into the pump body. Screw the check valve retainer into the pump body against the check valve cage and tighten it to 120–140 ***lb–in*** torque. Install the pump inlet elbow, using sealant (Permatex No. 2 or equivalent) on all of the threads except the last one nearest the open end of the elbow.

9. If the pump–to–reservoir return elbow and the plug were removed, apply sealant to all except the first thread on the elbow and plug and reinstall them.

10. Install the thrust ring in the counterbore of the pump body. Lay the fiber washer on the thrust ring.

11. Assemble the pump piston and the retaining spring in the pump body.

12. Install the needle bearing with its outer race in the retaining spring.

    The current belt–driven pumps incorporate a 5/8" diameter shaft. Former pumps used an 11/16" diameter shaft. When an old pump assembly or shaft is replaced by a current pump or shaft, a new pulley with a 5/8" bore must also be provided. The diameter of the pulley must be such that the pump will not exceed a constant speed of 2500 rpm.

13. *Slide the end of the pump shaft assembly through the* needle bearing, and the fiber washer into the thrust ring.

14. Affix a new gasket to the pump body. Assemble the bearing retainer to the pump body. Align the scribe marks previously made on the retainer and pump body and install the retaining bolts and lock washers.

15. Install a new oil seal in the bearing retainer as follows:

    a. Apply a thin coat of sealing compound to the outside diameter of the oil seal casing.

    b. Place the oil seal lip protector J 7191–2 over the shaft, lubricate the lip of the seal and slide the seal, lip side first, over the oil seal lip protector and down to the bearing retainer.

    c. Place the oil seal installer J 7191–1 over the seal lip protector J 7191–2, covering the threaded end of the shaft. Then press the seal in flush with the outer face of the retainer. Refer to (Figs. 16 and 18).

16. Install the pulley on the shaft.

17. Install the charging pump on the engine and connect the hydraulic hoses to the pump.

HAND PUMP

The hand pump (Fig. 19) is a single piston double-acting positive displacement type. It is mounted in such a manner that the pumping action is never in a vertical direction and the handle clears all obstructions throughout its complete stroke. The handle may be removed and stored when the pump is not in use.

The hand pump is used to provide the initial hydraulic pressure for a new Hydrostarter installation or to build-up the pressure in the Hydrostarter system if it has been released for any reason.

Flow through the pump is controlled by ball check valves. A manually operated relief valve is provided in the hand pump to release the pressure when servicing of any of the components in the Hydrostarter system is required.

Remove Hand Pump

Remove the hand pump as follows:

1. Release the pressure in the Hydrostarter system by opening the relief valve (Fig. 19) on the side of the pump approximately 1/2 turn.

   CAUTION: The oil pressure in the system must be released prior to servicing the hand pump or any other components of the system to prevent possible injury to personnel or equipment damage.

2. Clean all of the exterior dirt from the hand pump and the hydraulic hoses.
3. Disconnect the hydraulic hoses at the pump.
4. Remove the attaching bolts and lock washers and lift the pump from its mounting.

Disassemble Hand Pump

1. Withdraw the handle from the pump cam. Release the rubber boot from the pump body by removing the *retaining ring*.
2. Remove the two spring retainers and withdraw the pin.
3. Withdraw the cam and boot from the pump body.
4. Remove the four plugs, compression springs and check valve balls.
5. Remove the two plugs and metal gaskets and withdraw the piston, with the back-up rings and seal rings, from the pump body.
6. Remove the relief valve and ball. The pump inlet and outlet elbows and remaining plugs may be removed, if necessary, in order to clean or inspect the pump body.
7. Remove the seal rings and the seal back-up rings from the piston.

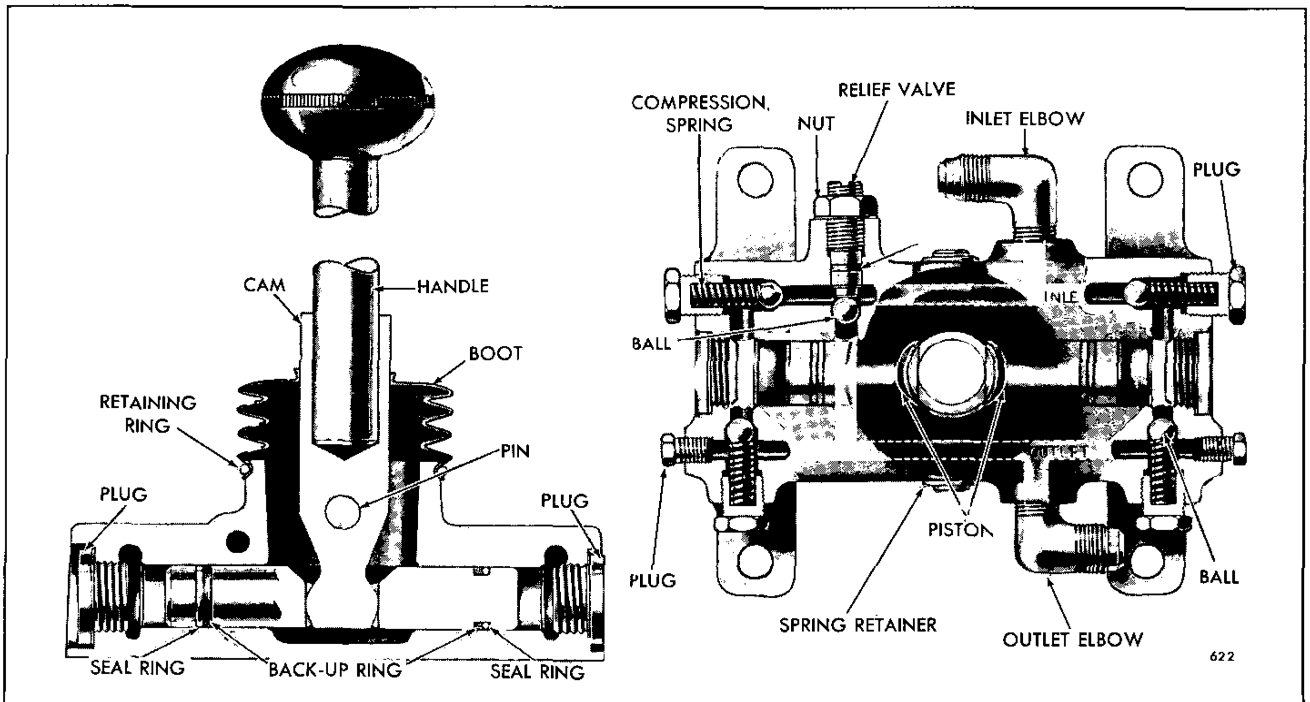


Fig. 19 – Cross Sections of Hydrostarter Hand Pump

Assemble Hand Pump

After an initial cleaning, inspect the pump parts. Stone the check valve ball seats in the pump body, if necessary. Then thoroughly clean the pump parts and reseat the balls in the pump body, using a non–hardened steel rod. Assemble the pump as follows:

1. Thoroughly soak new back–up rings in warm oil prior to installation. Slide the back–up rings and new seal rings on the piston.
2. Insert the piston in the pump body, notched side up, and secure it in place with plugs and new metal gaskets.
3. Clean and install the four check valve balls and springs. Install the retaining plugs.
4. If the pump inlet and outlet elbows and plugs were removed, reinstall them in the pump body. Use Permatex No. 2, or equivalent, on all male threads except the thread nearest to the open end.
5. Assemble a new seal ring on the relief valve, then insert the ball in place and secure it with the relief valve and lock nut.
6. Install the cam and insert the pin through the pump body and cam. Install the spring retainers on the pin. Install the rubber boot and secure it with a retaining ring.
7. Slide the handle into the cam.

Install Hand Pump

1. Secure the pump to its mounting with the attaching bolts and lock washers.
2. Refer to (Fig. 1) and connect the two hydraulic hoses to the pump. *Make sure the hoses and fittings are clean before any connections are made.*

ACCUMULATOR

Three different types of accumulators (Fig. 20) have been used with the Hydrostarter system. The accumulator consists of a heavy duty shell assembly and piston designed to hold the nitrogen pressure for an extended period of time.

The accumulator is preloaded with nitrogen through a small valve and sealed at the time of manufacture. A seal ring is assembled in the groove of the piston, between two teflon (formerly leather) back–up rings, to prevent the nitrogen from entering the hydraulic system. The nitrogen is stored in the air valve end of the accumulator and the fluid is discharged at the opposite end.

A rubber seal ring and a teflon (formerly leather) back–up ring are used at each cap to prevent the escape of fluid and nitrogen from the shell. Nitrogen is used because it is an inert gas that will not rust or corrode the piston or the accumulator. Also, it is expensive, non–toxic, non–explosive and readily available.

Oil enters the accumulator under pressure from either the engine–driven pump or the hand pump and forces the piston back, compressing the nitrogen gas and storing the energy to operate the system.

The accumulator is available in either 1–1/2 or 2–1/4 gallon capacity.

If a longer cranking period is desired, two or more accumulators may be connected in parallel, provided that a reservoir of sufficient capacity is used.

Service replacement accumulators are supplied with a precharge of nitrogen (1250 $\pm$ 50 psi).

Remove Accumulator

1. Release the oil pressure in the hoses and the accumulator by opening the relief valve (Fig. 1) on the side of the hand pump.

   CAUTION: The oil pressure in the Hydrostarter system must be released prior to servicing the accumulator or other components to prevent possible injury to personnel or equipment damage.

2. Clean all of the exterior dirt from the accumulator and the hydraulic hoses.
3. Disconnect the hydraulic hose at the accumulator.
4. Remove the pressure gage and the fittings from the fluid end cap of the accumulator.
5. Remove the attaching U bolts and lift the accumulator from its mounting.

Disassemble Accumulator

Normally, no maintenance of the accumulator is required other than painting to resist external corrosion. However, if there is a loss of the nitrogen precharge pressure due to a leaky air valve, indicated by bubbles in a soap solution applied around the valve, or due to leakage past the piston, indicated by bubbles and foaming in the reservoir, replace either the air valve or the piston seal rings as required. Seal rings between the end cap and the shell will rarely require replacement, unless the accumulator is disassembled.

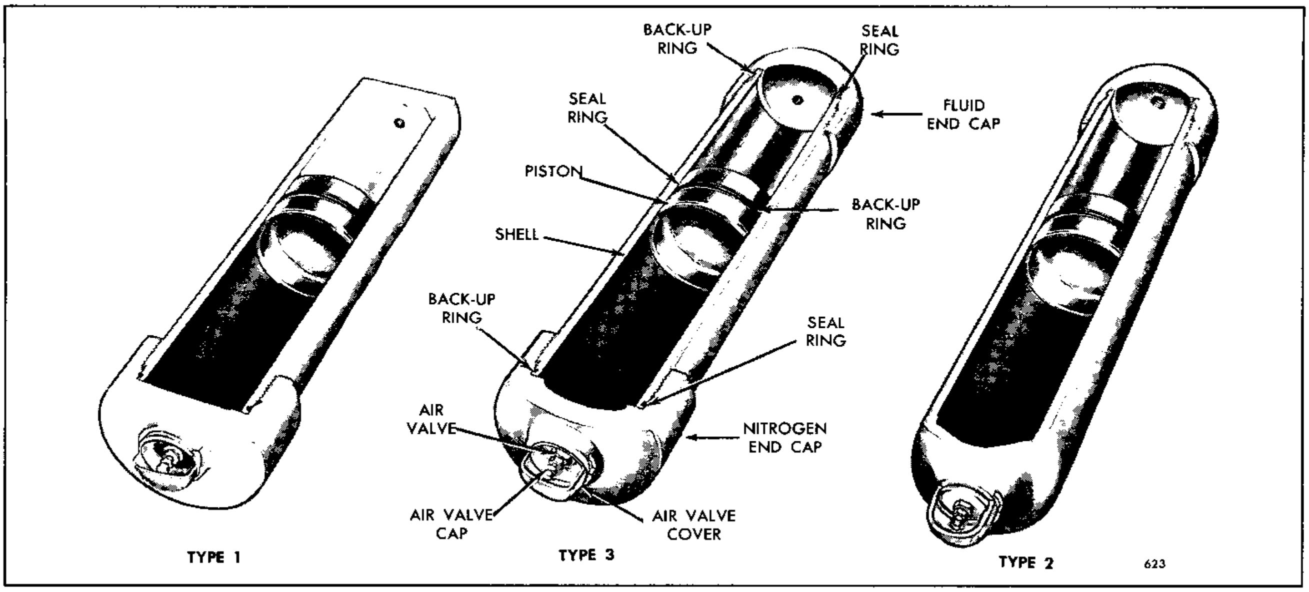


Fig. 20 – Cross Section of Typical Accumulators

1. If a defective air valve was the cause of leakage, remove the air valve cover (Fig. 20) from the accumulator cap and the air valve cap from the air valve. Loosen the 5/8" hex swivel nut on the air valve stem approximately 1–1/2 turns and then depress the valve core to release any remaining nitrogen pressure before removing the air valve. Remove the valve and replace it with a new part.

However, if damaged piston and cap seal rings are surmised, continue with the disassembly.

2. Remove the accumulator caps from the shell with a strap wrench, then push the piston out of the shell by hand.

On the former accumulator (TYPE 1 or 2), remove the cap from the shell with a strap wrench, then insert a rod through the tapped hole in the fluid end or air valve end of the shell and push the piston out of the shell. Do not damage the threads in the accumulator with the rod.

3. Remove and discard the seal ring and the back–up rings from the piston.

4. Remove and discard the seal rings and the back–up rings from the shell.

Assemble Accumulator

After cleaning the shell, piston and cap thoroughly, assemble the accumulator as follows:

1. Install new teflon back–up rings (Fig. 20) and new seal rings ("O" rings) in the grooves of the shell, with the seal ring nearest the open end of the shell (Fig. 21).

NOTICE: Make sure the teflon seal be installed is the ring groove of the shell so that the open ends do not catch on the threads of the steel cap when it is threaded into the end of the shell. Lubricate the seal ring and the sealing surface of the end cap with engine oil before installing the cap. Reverse positioning of the open ends of the back–up ring can cause contact between the ends and the cap itself. This can cause the back–up ring to buckle and result in an improper seal ring seal when the cap is threaded on the shell.

2. On the current TYPE 3 accumulator, install the fluid end cap on the shell, being careful not to damage the seal ring.

3. Assemble a new seal ring between the two new teflon back–up rings in the piston ring groove. To insure correct positioning of the seal ring ("O" ring) and the two teflon back–up rings, it is recommended that a suitable ring compressor with a diameter capacity of 3–1/2" to 7" and a 3–1/2" high compression band be used.

4. Install the ring compressor on the piston and rings and place the entire assembly on the open end of the shell (Fig. 22). Lubricate the inner surface of the ring compressor and the beginning inner region of the shell with engine oil to reduce friction between the piston and the shell.

5. Carefully drive the piston into the shell with a hammer and block of wood, tapping gently to slowly move the seal ring and back–up rings across the chamfered edge of the shell.

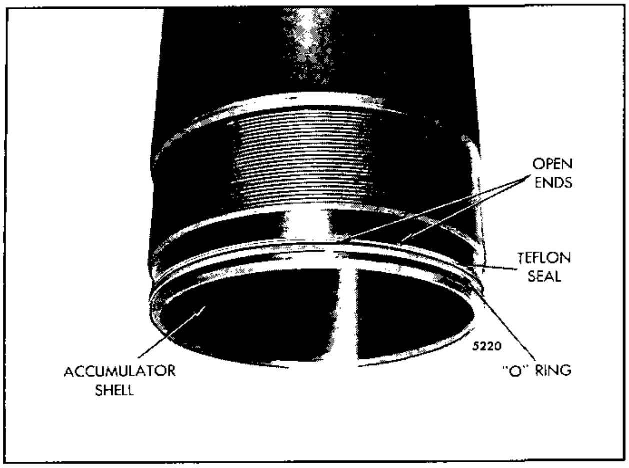


Fig. 21 – Proper Installation of Teflon Back–up Ring

a. On TYPE 1 and 3 accumulators, slide the piston, crown side first, into the shell.

   – On a TYPE 2 accumulator, slide the piston, crown side facing out, into the shell.

b. On TYPE 1 and 3 accumulators, install the nitrogen end cap on the shell.

   – On a TYPE 2 accumulator, install the fluid end cap on the shell.

6. Install the fittings and pressure gage in the fluid end cap. Use sealant (Permatex No. 2, or equivalent) on all male threads except the thread nearest the open end.

Install Accumulator

1. Secure the accumulator to its mounting with the U bolts.

2. Connect the hydraulic hoses to the accumulator. *Make sure the hoses and fittings are clean before any connections are made.*

Charge Accumulator

Use the following procedure in precharging an accumulator with commercial nitrogen.

1. Attach the gage end of charging kit J 6714–02 to the nitrogen tank (Fig. 23).

2. Remove the air valve cover (Fig. 20) from the accumulator cap and the cap from the air valve.

3. Install the air valve stem extension on the air valve.

4. Completely back–off the shaft pin in the air check valve connector on the charging kit hose and install the connector on the air valve stem extension. Draw the swivel nut up tight.

5. Loosen the 5/8" hex lock nut on the accumulator air valve stem by turning it counterclockwise. Do not turn the lock nut more than one and one–half turns.

6. Turn the shaft pin in the air check valve connector clockwise until the valve core in the air valve is depressed.

7. Charge the accumulator by opening the valve on the nitrogen tank and allow a small flow of nitrogen to enter the accumulator until the charging kit gage registers 1300 psi. Close the nitrogen tank valve.

To check the precharge pressure during charging, simply shut off the valve to the nitrogen tank, allow a small increment of time for the pressure to stabilize and the pressure indicated on the gage is the accumulator precharge pressure.

8. Back–off the shaft pin in the air check valve and tighten the 5/8" hex lock nut on the accumulator valve stem. This isolates the pressure in the charging kit hose.

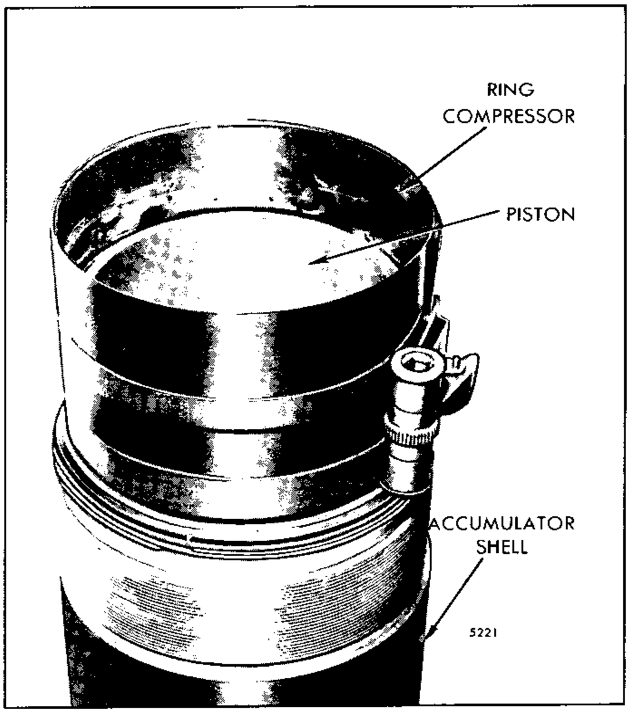


Fig. 22 – Installing Piston in Accumulator Shell

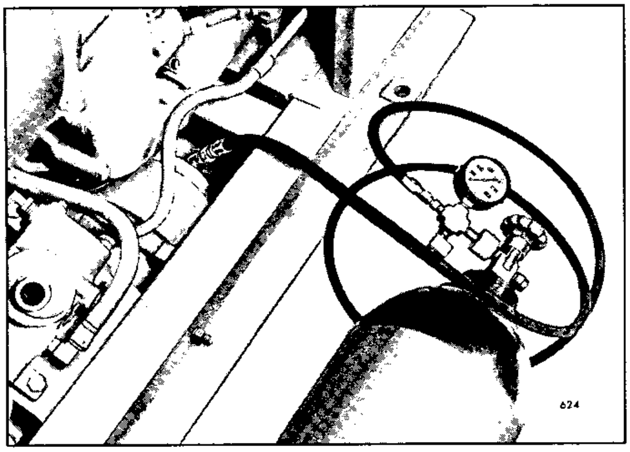


Fig. 23 – Charging Accumulator with Charging Kit J 6714-02

9. Depress the bleed–off valve on the pressure gage to reduce the pressure in the hose to zero.

10. Repeat Steps 5 and 6 to check for a precharge pressure of 1250 psi.

11. Disconnect the accumulator charging kit from the accumulator and from the nitrogen tank.

12. Check for gas leakage by applying a soap solution to the accumulator valve stem.

13. Replace the cap on the air valve and install the air valve cover on the accumulator cap.

14. Be sure Caution Decal ("CAUTION: This Vessel Pre–Charged to 1250 psi with Dry Nitrogen") is on accumulator.

RESERVOIR

The reservoir consists of a cylindrical steel tank of sufficient capacity to hold the entire oil supply for the Hydrostarter system. A filler cap and breather assembly, with a dry–type filter, is located at the top of the reservoir. A fine mesh screen at the reservoir outlet filters all of the fluid flowing to the suction side of the pump.

Reservoirs are available in two basic shapes to fit various installations. There are four sizes of reservoirs: 10, 12, 16 or 23 quart capacity. The size of the reservoir used depends upon the requirements of the particular Hydrostarter installation.

The supply hoses (Fig. 1) leading to the engine–driven pump and the hand pump are connected to the screen at the bottom of the reservoir. A return hose from the engine–driven pump connects to the top of the reservoir, while a drain hose from the Hydrostarter motor is connected to the fitting at the side of the reservoir.

The reservoir must be mounted (with the filler cap at the top) so that the outlet at the bottom of the tank is not more than 36" below nor 12" above the inlet of the engine–driven pump.

The reservoir requires very little attention other than periodically draining and flushing the old fluid out and cleaning the screen. After cleaning, fill the reservoir with new clean fluid. Make certain that the oil level is sufficient to completely cover the screen at the bottom of the reservoir. This check is made after the accumulator is charged and the engine–driven pump is by–passing oil to the reservoir.

FUEL SYSTEM PRIMING PUMP

The small compact priming pump (Fig. 24) is used to permit the operator to prime the injectors. Before starting the engine, the operator must make sure ample fuel is present in the injectors, fuel lines, fuel filters and fuel manifolds.

The priming pump requires very little service other than an occasional cleaning of the ball check valves in the inlet and outlet passages of the pump or replacement of the seal rings. To clean the ball check valves, remove the plugs, springs and ball check valves. Clean the parts with fuel oil and reinstall them in the pump.

To replace the seal rings, loosen the lock nut and withdraw the plunger. Discard the oil seal rings. Install new seal rings and insert the plunger carefully in the pump body. Tighten the lock nut.

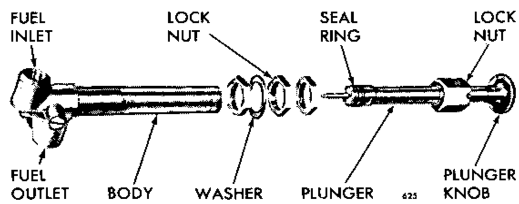


Fig. 24 – Fuel System Priming Pump and Relative Location of Parts

HYDRAULIC REMOTE CONTROL SYSTEM

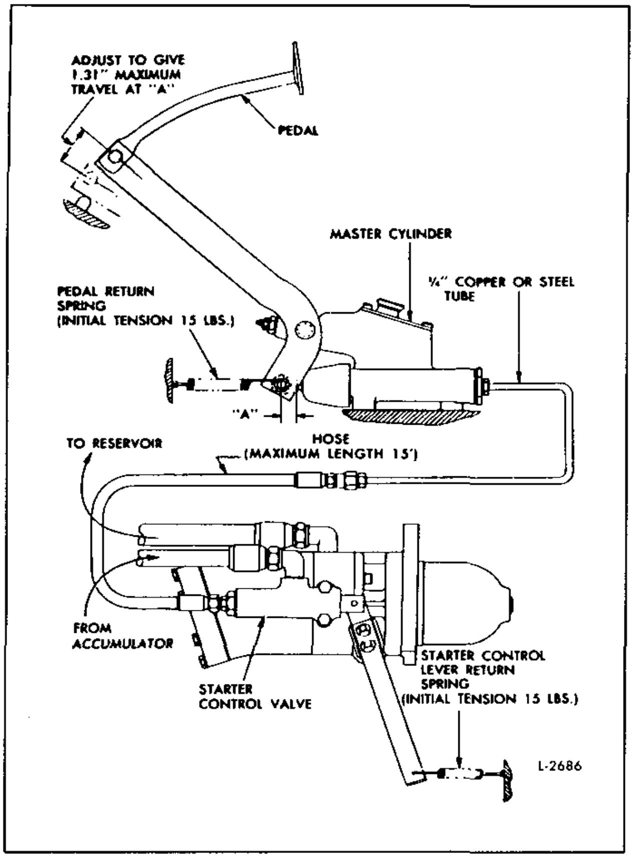


Fig. 25 – Hydraulic Remote Control System for Hydrostarter

The hydraulic remote control system consists of a master cylinder, a pedal, a lever arm, two springs and a flexible hose. It is an independent hydraulic system using diesel fuel oil as the hydraulic fluid to actuate the Hydrostarter control valve by means of the manually operated master cylinder.

The master cylinder (Figs. 25 and 26) is a single piston, positive displacement type of mechanism and is connected to the control valve on the Hydrostarter by a flexible hose. The fluid displaced by the piston is ported to the rear of the control valve.

Hydraulic pressure opens the control valve and engages the starter pinion with the engine flywheel ring gear in the proper sequence.

The master cylinder may be located at any desired location. However, for distances greater than 15 feet, 1/4" O.D. steel or copper tubing must be used between the flexible hose and the master cylinder. The flexible hose is always connected to the Hydrostarter control valve housing.

Current Hydrostarter motors are equipped with a control valve that incorporates a threaded valve housing plug with a 1/8" – 27 tapped hole in the center for installation of the flexible hose. A 1/8" – 27 vent plug is installed when the remote control system is not used. A cup plug was used in the valve housing on former Hydrostarter motors.

Springs are used to return the master cylinder piston and the Hydrostarter control lever to the off position. The springs have an initial tension of 15 lbs (Fig. 25).

The master cylinder lever arm must be adjusted to give the piston push rod a maximum travel of 1.31" (Fig. 25). The Hydrostarter control valve must be free to open to a minimum of 1-1/16".

The Hydrostarter remote control system may be purged of air as follows:

1. Fill the master cylinder with fuel oil.
2. Loosen the hose fitting at the Hydrostarter control valve.
3. Actuate the master cylinder pedal until all of the air is discharged from the system and a solid stream of fuel oil is being discharged with each stroke. Replenish the fluid in the master cylinder as required during the purging operation.
4. Tighten the hose fitting and check for leaks.

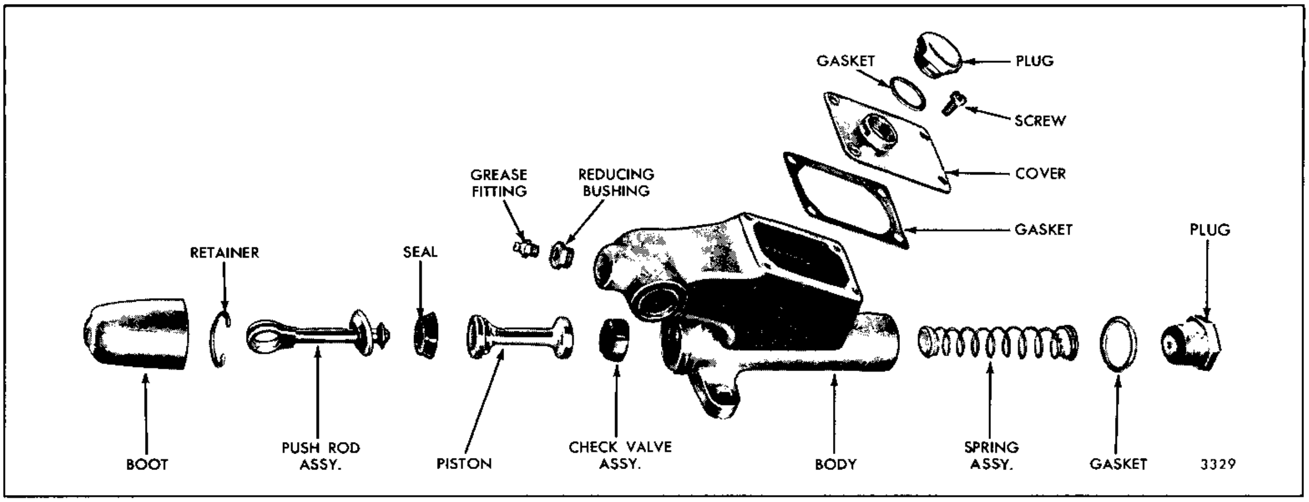


Fig. 26 – Hydraulic Starter Remote Control Master Cylinder Details and Relative Location of Parts

LUBRICATION AND PREVENTIVE MAINTENANCE

Inspect the system periodically for leaks. Primarily, examine the high pressure hoses, connections, fittings and the control valve on the starter. Make certain that the oil level in the reservoir is sufficient to completely cover the screen at the bottom of the tank. Make this check after the accumulator is charged and the engine–driven pump is by–passing oil to the reservoir.

Every 2000 hours, or as conditions warrant, drain the reservoir and remove the screen. Flush out the reservoir and clean the screen and filler cap. Then reinstall the screen.

Remove the bowl and element from the filter in the engine–driven pump supply hose (Fig. 1). Wash the bowl and element in clean fuel oil and reassemble the filter.

Release the pressure and drain the remaining hydraulic fluid from the system by disconnecting the hoses from the Hydrostarter components. Then reconnect all of the hydraulic hoses.

CAUTION: The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment damage.

NOTICE: Make sure all hoses and fittings are clean before any connections are made.

Fill the Hydrostarter system with new clean fluid as recommended.

Lubrication

Remove the Hydrostarter from the engine every 2000 hours for lubrication. Before removing the Hydrostarter, release the pressure in the system by means of the relief valve in the hand pump. Then remove the three bolts that retain the starting motor to the flywheel housing. Remove the starting motor without disconnecting the hydraulic hoses. This will prevent dirt and air from entering the hydraulic system.

Apply a good quality, lightweight grease on the drive clutch pinion to make sure the clutch will slide freely while compressing the spring. Also apply grease to the fingers of the clutch fork and on the spool of the clutch yoke engaged by the fork. This lubrication period may be reduced or lengthened according to the severity of service.

Remove the pipe plug from the starting motor drive housing and saturate the shaft oil wick with engine oil. Then reinstall the plug.

After lubricating, install the starting motor on the flywheel housing and recharge the accumulator with the hand pump.

On units equipped with a hydraulic remote control system, lubricate the shaft in the master cylinder through the pressure grease fitting every 2000 hours.

Cold Weather Operation

Occasionally, when an engine is operated in regions of very low temperatures, the starter drive clutch assembly may slip when the starter is engaged. If the clutch slips, proceed as follows:

1. Release the oil pressure in the system by opening the relief valve in the hand pump.

   CAUTION: The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment damage.

2. Disconnect the hydraulic hoses from the starting motor.
3. Remove the three retaining bolts and lock washers and withdraw the starting motor from the flywheel housing.
4. Disassemble the starting motor.
5. Wash the Hydrostarter drive clutch assembly in clean fuel oil to remove the old lubricant.
6. When the clutch is free, apply SAE 5W lubricating oil.
7. Reassemble the starting motor and reinstall it on the engine. Then attach a tag to the starter noting the lubricant used in the clutch.
8. Recharge the accumulator with the hand pump.

Marine Application

In addition to the normal Hydrostarter lubrication and maintenance instructions, the following special precautions must be taken for marine installations or other cases where equipment is subject to salt spray and air, or other corrosive atmospheres:

1. Clean all exposed surfaces and apply a coat of zinc–chromate primer, followed by a coat of suitable paint.
2. Apply a liberal coating of Lubriplate, type 130–AA, or equivalent, to the following surfaces.
   a. The exposed end of the starter control valve and around the control shaft where it passes through the clutch housing (Fig. 4).
   b. The exposed ends of the hand pump cam pin (Fig. 19).
3. Operate all of the moving parts and check the protective paint and lubrication every week.

Troubleshooting

The ability of the Hydrostarter system to provide positive starts under all conditions, with little service over a long period of time, depends primarily on proper maintenance.

Certain abnormal conditions that may interfere with the satisfactory performance of the Hydrostarter system, together with the methods of determining the cause of such conditions, are covered in the Troubleshooting Charts in Section 12.0.

Service

Before any work is performed, the oil pressure in the Hydrostarter system must be released to prevent possible injury to personnel or equipment.

Remove all of the exterior dirt before any portion of the hydraulic system is opened. Dust, dirt or other foreign material must never be allowed to enter the system.

TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS

TROUBLESHOOTING (Hydrostarter)

Chart 1

LOW OR NO ACCUMULATOR PRESSURE

ENGINE DRIVEN PUMP FAILS TO RAISE PRESSURE

Probable Causes

1. AIR IN SYSTEM
2. LOW FLUID LEVEL
3. SCREEN OR FILTER PLUGGED
4. CHECK VALVES NOT FUNCTIONING PROPERLY
5. DRIVE BELT SLIPPING (BELT–DRIVEN PUMP)
6. DRIVE ARM DEFECTIVE (DIRECT–DRIVEN PUMP)

SUGGESTED REMEDY

1. To purge the engine driven pump of air:
   a. Operate the engine at maximum no–load engine speed.
   b. Break the hose connection at the discharge side of the engine–driven pump until a full stream of oil is discharged from the pump.
   c. Connect the hose to the pump and alternately loosen and tighten the swivel fitting on the discharge hose until oil leaking out, when the fitting is loose, appears free of air bubbles.
   d. Tighten the fitting securely and observe the pressure gage. The pressure must rise rapidly to the accumulator precharge pressure (1,250 psi (8 619 kPa) at 70°F or 21°C), then increase slowly to 2,900 to 3,300 psi (19 996 to 22 754 kPa) in six to ten minutes, depending upon the size of the particular accumulator. If the accumulator pressure does *not* rise, make certain that the hand pump relief valve is closed after the pressure is released and repeat the above purging procedure.
2. The fluid level in the reservoir must be sufficient to completely cover the screen at the bottom of the tank after the accumulator is charged and the engine–driven pump is bypassing a full stream of fluid to the reservoir.
3. Remove and clean the reservoir screen and flush out the reservoir tank. Also, clean the filter located in the supply hose between the reservoir and the engine–driven pump.
4. Open the relief valve on the side of the hand pump, while the engine is running, to permit the engine–driven pump to wash the check valves free from particles.

   If the accumulator can be charged with the hand pump but not with the engine–driven pump, then a check valve in the engine pump is defective. Replace the faulty check valve assembly.
5. Adjust or replace the drive belt, if necessary.
6. Replace the pump drive arm.

Chart 2

CRANKING SPEED TOO LOW

Probable Causes

1. HYDROSTARTER SYSTEM FLUID TOO HEAVY
2. ENGINE OIL TOO HEAVY
3. CONTROL VALVE NOT FULLY OPEN

SUGGESTED REMEDY

1. Check the mixture of fluid in the system. Use fluid consisting of 75% diesel fuel and 25% SAE 10 or 30 lubricating oil.
2. Replace the oil with the proper viscosity grade. Refer to the *Lubrication Specifications* in Section 13.3.
3. Check the travel of the control valve located on the side of the starter. Minimum travel is 1-1/16". Remove any obstruction that prevents sufficient control valve or control lever handle travel.

Chart 3

LOSS OF FLUID FROM RESERVOIR

Probable Causes

1. EXTERNAL LEAKS
2. WORN STARTER SHAFT SEAL
3. DEFECTIVE GASKET UNDER STARTER COVER
4. WORN SHAFT SEAL (BELT-DRIVEN PUMP)
5. WORN SHAFT SEAL (DIRECT-DRIVEN PUMP)

SUGGESTED REMEDY

1. With pressure in the system, check all hoses and fittings for leaks. Tighten or replace the fittings and any defective parts.
2. Remove the starter after releasing the system pressure and observe the inside of the clutch housing. If evidence of system fluid is found, replace the shaft seal.
3. Operate the starter. During the cranking cycle, watch closely for fluid leaking around the cover or any of the retaining bolts.
4. While the pump is bypassing at full system pressure, examine the shaft for evidence of leaks. Replace the seal, if necessary.
5. After the pump has been bypassing at full system pressure, remove the pump from the flywheel housing and examine the back of the mounting plate near the seal for evidence of leaks. Replace the shaft seal, if necessary.

Chart 4

LOSS OF FLUID PRESSURE WHEN ENGINE IS NOT RUNNING

Probable Causes

1. AMBIENT TEMPERATURE DECREASE
2. ENGINE DRIVEN PUMP CHECK VALVES NOT HOLDING
3. HAND PUMP VALVES NOT HOLDING
4. DAMAGED SEAL RING IN STARTER CONTROL VALVE SHOWN BY EXTERNAL LEAKAGE
5. DAMAGED MIDDLE SEAL RING IN STARTER CONTROL VALVE, NO VISIBLE EXTERNAL LEAKAGE
6. EXTERNAL LEAKAGE IN SYSTEM
7. STARTER CONTROL VALVE OUT OF TIME – BENT SHIFTING FORK
8. LOSS OF ACCUMULATOR PRE–CHARGE (NITROGEN)

SUGGESTED REMEDY

1. A drop in temperature will decrease the nitrogen pressure. Adjust the pressure as needed for cranking requirements by use of the hand pump.

2. Disconnect the return hose and inlet hose from the engine–driven pump. Leakage from the inlet fitting means that both check valves are defective. Leakage at the return fitting means that only the outlet check valve is defective. Replace the defective check valve assembly(s).

3. Disconnect the inlet hose from the hand pump. Leakage from the inlet fitting means that either the relief valve alone or both the inlet and outlet check valves are defective. Stone and clean the ball seats in the pump body and replace the balls and springs, if necessary.

4. Remove the control valve from the starter and replace the seal ring.

5. Disconnect the return hose from the starter. Use the hand pump to raise the pressure, if necessary. If fluid leaks from the return fitting when the control valve is closed, the middle seal ring is damaged. Remove the control valve and replace the seal ring.

6. Examine all hoses and fittings for leaks. Tighten or replace the fittings and any defective parts.

7. With the control valve closed, check the length of the piston protruding beyond the valve body. The correct length is $7/8'' \pm 1/32''$. If the length is incorrect, the shifting fork may be bent or the nylong yoke between the fork and the clutch collar may be damaged. Replace the faulty parts.

8. See Chart 7.

Chart 5

HAND PUMP FAILS TO DISCHARGE FLUID

Probable Causes

1. MANUAL RELIEF VALVE OPEN
2. CHECK VALVES LEAKING
3. RESERVOIR SCREEN PLUGGED
4. FLUID LEVEL LOW
5. AIR IN SYSTEM
6. DIRT IN PUMP
7. PISTON SEAL RINGS DAMAGED

SUGGESTED REMEDY

1. Close the relief valve.
2. If caused by dirt, open the relief valve and operate the hand pump slowly for a few minutes to wash the particles out of the check valves. If this is unsuccessful, stone and clean the ball seats in the pump body and replace the balls and springs, if necessary.
3. Remove and clean the reservoir screen, flush the reservoir tank and reassemble.
4. The fluid level in the reservoir must be sufficient to completely cover the screen at the bottom of the tank after the accumulator is charged and the engine–driven pump is bypassing a full stream of fluid to the reservoir.
5. To purge the hand pump of air:
   a. Relieve any system pressure, then disconnect the outlet hose from the hand pump.
   b. Close the manual relief valve and operate the pump until fluid is discharged when stroking in both directions.
   c. Reconnect the outlet hose.
6. See Item 2.
7. Replace the seal rings.

Chart 6

STARTER TURNS BUT ENGINE DOES NOT

Probable Causes

1. PINION NOT ENGAGING FLYWHEEL RING GEAR
2. PINION CLUTCH SLIPPING (COLD WEATHER OR HEAVY LIBRICANT)
3. OVERRUNNING CLUTCH BURNED OUT
4. STARTER ASSEMBLED WRONG

SUGGESTED REMEDY

1. Check the shifting fork. If the fork is bent, replace it.
2. Wash out the heavy lubricating oil and replace it with SAE 5W or SAE 10 oil.
3. Replace the clutch. If a mechanical linkage is attached to the control lever, add sufficient spring force to assure that the clutch is withdrawn from engagement, and that the control valve is returned to the *shut off* position. If no mechanical linkage is used, disengage the starter as soon as the engine starts. Prolonging the period during which the clutch overruns will reduce clutch life.
4. The starter may be assembled for L.H. rotation but with a R.H. overrunning clutch. Remove the starter and assemble it correctly.

Chart 7

LOSS OF ACCUMULATOR PRE-CHARGE (NITROGEN)

Probable Causes

1. DAMAGED SEAL RING ON PISTON
2. DEFECTIVE AIR VALVE
3. DAMAGED SEAL RING BETWEEN SHELL AND END CAP

SUGGESTED REMEDY

1. With some nitrogen precharge but no fluid pressure in the system, bubbles and foaming in the reservoir indicate that the nitrogen is leaking past the seal ring on the accumulator piston. Overhaul the accumulator.
2. Release the pressure in the system by opening the relief valve on the side of the hand pump. Then, loosen the hex locknut on the nitrogen valve approximately 3/4 turn to release the remaining precharge before attempting to remove the valve from the accumulator. Replace the air valve.
3. Apply light oil on the threaded end of the accumulator at the end of the cap. Bubbling of the oil indicates a leak past the end cap seal. Release the nitrogen precharge before removing the cap to replace the seals.

Chart 8

HIGH PRESSURE IN SYSTEM (3500 psi (24 133 kPa) or above)

Probable Causes

1. DEFECTIVE GAGE
2. ENGINE DRIVEN PUMP UNLOADING VALVE NOT OPERATING PROPERLY

SUGGESTED REMEDY

1. Replace the gage.
2. Overhaul the pump.

Chart 9

FLUID EMERGES FROM RESERVOIR FILLER CAP WHEN STARTER IS USED

Probable Causes

1. FILTER ELEMENT IN FILLER CAP LOADED WITH DIRT
2. NITROGEN IN FLUID RETURNED TO RESERVOIR
3. EXCESS FLUID IN RESERVOIR

SUGGESTED REMEDY

1. Rinse the filler cap thoroughly in fuel oil and dry it with compressed air.
2. Overhaul the accumulator. With some nitrogen precharge but no fluid pressure in the system, bubbles and foaming in the reservoir indicate that the nitrogen is leaking past the seal ring on the accumulator piston. Overhaul the accumulator.
3. Check the fluid level after the accumulator is charged and the engine–driven pump is bypassing a full stream of oil to the reservoir. The fluid level must be sufficient to completely cover the screen in the bottom of the tank.

Chart 10

FLUID EMERGES AROUND RUBBER BOOT ON HAND PUMP

Probable Causes

1. DAMAGED PISTON SEAL RINGS

SUGGESTED REMEDY

1. Replace the seal rings and leather back–up rings on the pump piston.

Chart 11

FLUID EMERGES FROM ENDS OF STARTER CONTROL VALVE WHEN STARTER IS OPERATED

Probable Causes

1. DAMAGED FRONT CONTROL VALVE SEAL RING
2. BENT SHIFTING FORK CAUSING END OF CONTROL VALVE TO MOVE PAST THE REAR SEAL RINGS

SUGGESTED REMEDY

1. Operate the starter. If fluid emerges around the front end of the control valve, the seal ring is damaged.
2. With the control valve closed, check the length of the piston protruding beyond the valve body. The correct length is 7/8" ± 1/32". If the length is incorrect, the shifting fork may be bent or the nylon yoke between the fork and the clutch collar may be damaged. Replace the faulty parts.

Also, operate the starter. If fluid emerges from the cap on the rear of the control valve, the fork is bent and the seal ring may be damaged.

HYDROSTARTER SPECIFICATIONS

Hydrostarter Motor

Type	Swash plate
Number of pistons	Seven
Displacement per revolution *20 Series*	2 cu. in. (32.8 cu. cm^3)
Displacement per revolution *35 Series*	3.5 cu. in. (57.4 cu. cm^3)
Maximum torque at 3000 psi *20 Series*	80 lb–ft (108 N·m)
Maximum torque at 3000 psi *35 Series*	140 lb–ft (190 N·m)
Drive	Overrunning clutch
Inlet port *20 and 35 Series*	No. 8 elbow (JIC 37° flare)
Return port *20 Series*	No. 10 elbow (SAE 45° flare)
Return port *35 Series*	No. 12 elbow (SAE 45° flare)

Engine–Driven Pump

Type	Positive displacement
Number of pistons	One
Displacement per revolution	0.0208 cu. in. (.400 cu. cm^3)
Inlet port	No. 6 elbow (SAE 45° flare)
Outlet port	No. 6 elbow (J1C 37° flare)
Bypass port	No. 4 elbow (SAE 45° flare)
Maximum discharge pressure	3250 psi (22 409 kPa)
Maximum continuous speed	2500 rpm

Manual Pump

Type	Positive displacement
Number of pistons	One
Displacement per stroke	0.773 cu. in. (12.67 cu. cm^3)
Inlet port	No. 6 elbow (SAE 45° flare)
Outlet port	No. 6 elbow (J1C 37° flare)

Accumulator

Type	Piston
Capacity	200 or 300 cu. in. (3278 or 4916 cu. cm^3)
Precharge (nitrogen)	*1250 psi (8 619 kPa)*
Operating pressure	2900–3000 psi (19 996–20 685 kPa)
Port	3/8 NPTF

Reservoir

Capacity	10, 12, 16 or 23 qt. (9.5, 11.4, 15.1 or 21.8 liters)
Outlet port	1/4 NPT
Pump return port	1/8 NPT
Starter return port	1/2 NPT
Drain (plug) port	1/8 NPT

Remote Control Master Cylinder

Type	Positive displacement
Number of pistons	One
Displacement per stroke	1.2 cu. in. (19.7 cu. cm^3)
Outlet port	7/16–24 inverted flare tap

Filter

Type	Sediment bowl–stacked disc
Degree of filtration	50 microns
Inlet port	1/8 NPTF
Outlet port	1/8 NPTF

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	260M BOLTS TORQUE N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	280M OR BETTER TORQUE N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255–M	1	No. 6 thru 1 1/2	60,000
None	GM 260–M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280–M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275–M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290–M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300–M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455–M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

SERVICE TOOLS

TOOL NAME	TOOL NO.
Air Compressor Hub Remover	J 36309
Air Compressor Hub Installer	J 36311
Accumulator charging Kit	J 6714–D

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

NOTICE: Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Remove the filler cap and fill the cooling system with a coolant specified under *Coolant Specifications* in Section 13.3. Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Close the vents, if used, after filling the cooling system.

On marine installations, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet and pouring water into the pump.

NOTICE: Failure to prime the raw water pump may result in damage to the pump impeller.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time. Insufficient lubrication at start–up can cause serious damage to the engine components.

To ensure an immediate flow of oil to all bearing surfaces at initial engine start–up, DDC recommends that the engine lubrication system by charged with a commercially available pressure prelubricator. Use the following procedure:

1. Remove the pipe plug from the engine main oil gallery and attach the pre–lubricator hose.
2. Remove the valve rocker cover(s) and, using a positive displacement pump set at 25–35 psi (172–241 kPa), pump in the recommended grade of engine lubricating oil until it is observed flowing from the rocker arms.
3. If the engine is turbocharged, disconnect the oil supply lines at the turbocharger bearing (center) housing and fill the bearing housing cavities with approximately one pint of the recommended grade of clean engine oil. Turn the rotating assemblies by hand to coat all internal surfaces with oil and reinstall the turbocharger oil supply lines.
4. After 20 minutes, check the crankcase oil level. Add enough oil to bring the level to the "full" mark on the dipstick. *Do not overfill.*
5. Disconnect the pre–lubricator hose, plug the main oil gallery hole and replace all components previously removed.
6. Before initial engine start–up, DDC also recommends cranking the engine with the governor in the *no–fuel* position until oil pressure registers on the gage.

For engine lubricating oil recommendations, see *Lubricating Oil* in Section 13.3 or contact a Detroit Diesel distributor.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy–duty* lubricating oil as specified under *Lubricating Oil* in Section 13.3. Then, prelubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Turbocharger

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

1. Clean the area and disconnect the oil inlet line at the bearing housing.
2. Fill the bearing housing cavity with clean engine oil.
3. Reinstall the oil line. Clean off any spilled oil.

4. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig – 69 kPa at idle speed).

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds.

Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill *the air cleaner oil cups to the proper level with clean engine* oil. *Do not overfill.*

Transmission

Check the oil level and, if necessary, fill the transmission case, marine gear or torque converter supply tank to the proper level with the lubricant specified under *Lubrication and Preventive Maintenance* in Section 15.1.

Fuel System

Fill the fuel tank with the fuel specified under *Fuel Specifications* in Section 13.3.

If the unit is equipped with a fuel supply shutoff valve, it must be opened. Special note should be taken of the direction of flow through any check valves used in the system to be sure of their proper installation.

To ensure prompt starting and even running, the fuel system must be purged of air and full of fuel from the supply tank to the restricted fitting at the fuel return line. To accomplish this, a manual priming pump, such as J 5956 or an electrical type priming pump can be adapted easily to the fittings provided on the primary or secondary filters. To be sure the injectors are lubricated and in order to have less resistance to priming flow caused by the static fuel pump, priming through the secondary filter is preferred. The system should be primed until no air is present in the fuel flow from the return line. Pressure should not exceed 15 psi (103 kPa) for ease of handling and safety reasons.

Pressurization of the fuel tank, although not recommended, can be used with controlled air pressure and a modified filler cap (do not exceed 15 psi or 103 kPa). If this system is used, be sure the return line from the head is disconnected to bleed the system, or no flow will occur. Reverse flow through the return line should be avoided to prevent reverse flushing of filters and flushing residue from the fuel tank into the injectors. Special provisions may have to be made on dual tanks to prevent loss of pressure from the vent on the tank opposite the tank being pressurized.

Priming is not always necessary if the filter elements are filled with fuel when installed and the manifolds in the head are not drained of fuel. Prolonged use of the starter motor and engine fuel pump to prime the system can result in damage to the starter, fuel pump, injectors and erratic running of the engine, due to the amount of air in the lines and filters from the supply tank to the cylinder head.

Engines equipped with starting devices dependent on compressed air or gas reservoirs should always be primed prior to initial start–up, otherwise reserve pressure can be exhausted. Injectors can be damaged from lack of lubrication and cooling.

> **NOTICE:** Under no circumstances should a starting aid such as ether be used to run the engine until the fuel system is primed. Injector damage will occur is this method is used. The heat generated by the external fuel source will cause the tips to be damaged when the fuel cools them. The plunger and bushing can be scored from running without lubrication.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings (except for fan hub pulley fitting—refer to Section 15.1) with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance* in Section 15.1.

• Storage Battery

Check the battery. The top should be clean and dry, the *terminals tight and protected with a coat of petroleum jelly.* Check the "Eye" of maintenance–free batteries for charge. Check standard lead–acid and semi–maintenance free batteries, when necessary, with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Generator Set

Where applicable, fill the generator end bearing housing with the same lubricating oil as used in the engine. A generator set should be connected and grounded in accordance with the applicable local electrical codes. The base of a generator set *must* be grounded.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

If a manual or an automatic shutdown system is incorporated in the unit, the control must be set in the *open* position before starting the engine. On engines with dual air shutdown housings, both air shutoff valves must be in the *open* position before starting the engine.

NOTICE: The blower will be seriously damaged if operated with the air shutoff valve in the *closed* position.

Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid. See *Cold Weather Starting,* Section 12.6. The instructions for the use of a cold weather fluid starting aid will vary depending on the type being used. Reference should be made to these instructions before attempting a cold weather start.

CAUTION: Starting fluid used in capsules is highly inflammable, toxic and possesses sleep–inducing properties.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no–load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the *run* position; on hydraulic governors, make sure the stop knob is pushed all the way in. Then, press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

NOTICE: To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

• Initial Engine Start (Air Starter)

Because of the limited volume of most storage tanks and the relatively short duration of the cranking cycle, it is important to make sure the engine is **ready to start** before activating the air starter. Start an engine equipped with an air starter as follows:

1. Set the speed control lever at part throttle, then bring it back to the desired no–load speed. In addition, make sure the stop lever on the cover of mechanical governors is in the **run** position. On hydraulic governors, make sure the stop knob is pushed all the way in.
2. Check the pressure in the air storage tank. If necessary, add air to bring the pressure up to at least the recommended minimum for starting.
3. Press the starter button firmly and hold until the engine starts.

Initial Engine Start (Hydrostarter)

Start an engine equipped with a hydrostarter as follows:

Use the priming pump to make sure the fuel filter, fuel lines and injectors are full of fuel before attempting to start the engine.

Raise the hydrostarter accumulator pressure with the hand pump until the gage reads as indicated in Table 1.

Ambient Temperature	Pressure Gage Reading	
	psi	kPa
Above 40° F (4.4° C)	1500	10 342
40 - 0° F (4.4 to -18° C)	2500	17 237
Below 0° F (-18° C)	3300	22 753

TABLE 1

Set the engine controls for starting with the throttle at least half open.

During cold weather, add starting fluid at the same time the hydrostarter motor lever is moved. Do not wait to add the fluid after the engine is turning over.

Push the hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve as soon as the engine starts (to conserve the accumulator pressure and to avoid excessive over–running of the starter drive clutch assembly).

• "SILVER 53" ENGINE COLD START RECOMMENDATIONS/ADJUSTMENTS

If cold weather starting difficulties are experienced with Series 53 Silver engines, the following recommendations should be adhered to for optimum unaided cold start performance:

1. Fuel should be No. 2–D with a minimum cetane number of 45 (refer to "Fuel Oil Selection" in section 13.3).
2. A 12–volt system should use one (1) 625 CCA (cold cranking amp) battery for in–line engines, two (2) 625 CCA batteries for V–engines. Circuit resistance should not exceed .0012 ohms.
3. A 24–volt system should use two (2) 625 CCA batteries and circuit resistance should not exceed .002 ohms.
4. All in–line Silver 53 engines are equipped with Delco 40 MT or 37 MT starters. Older engines may have 30 MT starters, which may not provide adequate cranking speed for colder climates. The 6V–53 Silver engines must use 40 MT starters.
5. Parasitic loads at starting should be minimized. A minimum cranking speed of 130 rpm at 30°F (-1.11° C) must be maintained for successful cold start *characteristics. A cold diesel engine does not produce* as much torque at lower rpm as an engine at normal operating temperatures. For this reason, applications where the parasitic load is in excess of 50 lb–ft (68 N·m) torque at cranking speed may result in *unsatisfactory cold start characteristics.*

STARTING. For temperatures below 30°F (-1.11° C), use this starting procedure:

Holding the governor out of fuel, crank the engine for 15 seconds. Ease the governor into fuel while continuing to crank for an additional 15 seconds. If ether is used, inject while the engine is being cranked in fuel. Allow the starter to cool for 15 seconds and continue with 30–second cranking periods, separated by 15–second cool down periods, until the engine starts.

NOTICE: *Overfueling or "flooding" the engine during cold start will reduce compression tempereatures, wash lube oil from cylinder walls, reduce compression pressure, and decrease the likelihod of a successful start.*

If these recommendations do not solve the starting difficulty, it may be necessary, in some cases, to retune the engine to the specifications shown in the chart. These settings apply to engines using 5C and 5E fuel injectors only.

Injector Timing/Modulator Setting		
	Standard	Cold Start*
3–53T	1.480/ .290	1.500/ .200
4–53T	1.480/ .290	1.500/ .200
6V–53T	1.480/ .290	1.500/ .290

* The rack setting tool used for a .200 modulator setting is J35586. The 1.500 injector timing tool is J 25454.

NOTICE: *The above timing changes are not to be made on early (non–Silver) Series 53 engines EPA–certified for highway service.*

These changes can be made on a permanent basis or at change of seasons, whichever is preferred. It should be noted that changing to 1.500 injector timing could result in a slight increase in fuel consumption, compared to standard timing at SAE standard conditions. The .200 modulator setting may slightly increase visible smoke levels as well.

Temperatures below 30°F (-1.11° C) may require some of the following special considerations:

1. Cold weather fuel and/or oil selection (Refer to Section 13.3 for recommendations).
2. Water jacket (coolant) heater.
3. Lubricating oil heater (oil pan).
4. Hot air space heaters applied to engine compartment.
5. Cold weather hydraulic fluids if accesory pumps cannot be disengaged.
6. Insulated or heated battery boxes for maximum battery efficiency.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the *Troubleshooting Charts* in Section 15.2.

Warm–Up

Run the engine at part throttle and no load for approximately five minutes, allowing it to warm–up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections, where necessary, to stop leaks.

Engine Temperature

See Section 13.2 for normal engine coolant temperature.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached. Allow the oil to drain back into the crankcase for approximately twenty minutes and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick. *Do not overfill.*

Use only the *heavy duty* lubricating oil specified under *Lubricating Oil* in Section 13.3.

Clutch

Do not engage the clutch (with a sintered iron clutch plate) at engine speeds over 850 rpm. A clutch with an asbestos or vegetable fiber material clutch plate must not be engaged at speeds over 1,000 rpm.

Cooling System

Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level.

CAUTION: Use extreme care when removing the coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

The coolant level should be near the top of the opening. If necessary, add clean soft water or an ethylene glycol base antifreeze.

Transmission

Check the marine gear oil pressure. The operating oil pressure range at operating speed varies with the gear used. Refer to the gear manufacturer's recommendations. Check the oil and, if necessary, add oil to bring it to the proper level.

Turbocharger

• CAUTION: Do not hold the compressor wheel for any reason while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine. When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the *neutral* position.
2. Allow the engine to run at half speed or slower with no load for four or five minutes, then move the stop lever to the *stop* position to stop the engine.

Emergency Stopping

To stop an engine (normal or emergency) equipped with the spring–loaded (one screw) design injector control tube, pull the governer stop lever to the *stop* position.

If an engine equipped with the non–spring loaded (two screw) design injector control tube does not stop after using the normal stopping procedure, pull the *Emergency Stop* knob all the way out. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected.

NOTICE: The emergency shutdown system should never be used except in an emergency. Use of the emergency shutdown can cause oil to be sucked past the oil seals and into the blower housing.

The air shutoff valve, located on the blower air inlet housing, must be reset by hand and the *Emergency Stop* knob pushed in before the engine is ready to start again.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Drain the condensation from the exhaust line or silencer.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

Crankcase

Allow the oil to drain back into the crankcase for approximately twenty minutes and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy–duty* lubricating oil specified under *Lubricating Oil* in Section 13.3.

Transmission

Check and, if necessary, add sufficient oil to bring it to the proper level.

Inspection

Make a visual check for leaks in the fuel, lubricating and cooling systems.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to the *Lubrication and Preventive Maintenance Chart* in Section 15.1 and perform all of the daily maintenance operations. Also, perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which may have occurred during the previous run.

ENGINE OPERATING CONDITIONS

2–53, 3–53 and 4–53 ENGINES
(2–Valve Cylinder Head)

	1200 rpm #	1800 rpm	2000 rpm	2200 rpm
Lubrication System				
Lubricating oil pressure (psi):				
Normal (2–53 and 4–53)	30–50	40–60	40–60	40–60
Normal (3–53)		45–65	45–65	45–65
Minimum for safe operation	18	30	30	30
†Lubricating oil temperature (deg. F) – Normal:				
(2–53)	190–230	190–220	190–225	
(3–53 and 4–53)		200–235	200–235	200–235
Air System				
Air box pressure (inches mercury) – min. full load:				
At zero exhaust back pressure (2–53)	2.0	4.1	5.2	
At zero exhaust back pressure (3–53, 4–53)		3.8	4.9	6.2
At max. full load exh. back press. (2–53)	3.0	5.7	7.2	
At max. full load exh. back press. (3–53, 4–53)		5.5	6.9	8.6
Air inlet restriction (inches water) – full load max.:				
Dirty air cleaner – oil bath or dry type (2–53)	6.8	13.4	16.0	
Dirty air cleaner – oil bath or dry type (3–53, 4–53)	6.8	13.4		18.8
Clean air cleaner:				
2–53 oil bath type	4.5	9.5	10.8	
3–53, 4–53 oil bath type	4.5	9.5	10.8	12.0
2–53 dry type with pre–cleaner	4.5	6.8	10.8	
3–53, 4–53 dry type with pre–cleaner	4.5	6.8	10.8	12.0
2–53 dry type less pre–cleaner	3.0	5.5	6.5	
3–53, 4–53 dry type less pre–cleaner	3.0	5.5	6.5	7.4
Crankcase pressure (inches water) – max.	0.5	0.5	0.5	0.5
Exhaust back pressure (inches mercury) – max.:				
Full load	1.3	2.1	2.5	3.0
§Full load (fork lift truck)	4.2	9.7	12.1	
No load	0.6	1.3	1.7	2.1
§No load (fork lift truck)	2.5	6.0	7.5	
Fuel System				
Fuel pressure at inlet manifold (psi)				
Normal with .070″ restriction	45–60	45–70	45–70	45–70
Minimum	35	35	35	35
Fuel spill (gpm) – min. at no load:				
.070″ restriction	0.6	0.6	0.6	0.6
Pump suction at inlet (inches mercury) – max.:				
Clean system	6.0	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0	12.0

	1200 rpm #	1800 rpm	2000 rpm	2200 rpm
Cooling System				
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185	160–185
Raw water pump:				
Inlet restriction (inches mercury) – max.		& 8.0	& 8.0	8.0
Outlet pressure (psi) – max..		&10.0	&10.0	10.0
Keep cooler pressure drop (psi)				
Maximum through system		& 6.0	& 6.0	6.0
Compression				
Compression pressure (psi at sea level):				
Average – new engine at 600 rpm 525				
Minimum at 600 rpm 475				

3–53, 4–53, 6V–53, 8V–53 and 53N ENGINES (4–Valve Cylinder Head)

	2200 rpm	2500 rpm	2800 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal (4–53, 6V–53 and 8V–53)	40–60	40–60	40–60
Normal (3–53)	40–65	40–65	40–65
Minimum for safe operation	30	32	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	205–240
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	3.7	4.8	6.1
At max. exhaust back pressure	5.4	8.0	9.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – oil bath or dry type	18.8	23.0	25.0
Clean air cleaner – oil or dry w/pre–cleaner	12.0	14.0	16.0
Clean air cleaner – dry type withour pre–cleaner	7.4	8.7	10.0
Crankcase pressure (inches water) – max.	0.8	0.9	1.0
■ Crankcase pressure (inches water) – max.	1.1	1.2	1.3
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	& 4.0	+ 4.0
§ Full load (fork lift truck)	6.5	8.4	10.5
× Full load (6V–53 Veh.)	3.0	4.0	6.0
No load	2.1	& 2.7	++ 2.7
§ No load (fork lift truck)	4.2	5.5	7.0
× No load (6V–53 Veh.)	2.1	2.7	3.2

	2200 rpm	2500 rpm	2800 rpm
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45–70	45–70	45–70
Minimum	35	35	35
Fuel spill (gpm) – min. at no load:			
.070″ restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Raw wate pump:			
Inlet restriction (inches mercury) – max.	& 5.0	& 5.0	5.0
Outlet pressure (psi) – max..	&10.0	&10.0	10.0
Keep cooler pressure drop (psi)			
Maximum through system	& 6.0	& 6.0	6.0
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm . . . 480			
Average – new "N" engine – at 600 rpm . . . 590			
Minimum – at 600 rpm . . . 430			
Minimum – "N" engine – at 600 rpm . . . 540			

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

+ Marine engines only 5.5 inches mercury at 2800 rpm.

+ + Marine engines only 3.8 inches mercury at 2800 rpm.

▪ For 53 N engines with front cover breathing systems only.

& Maximum when this is the full-load engine speed.

× For 6V53 N (Veh.) engines with certification label build date of June, 1978 or later.

§ Fork lift trucks only when performance required is less than rated for injector, used as power loss may be as high as 9–12% at maximum rpm.

#2–53 reefer car engines only.

3-53 TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm	2600 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40–60	40–60	40–60
Minimum for safe operation	36	36	36
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure			
5A55 injector – 118 BHP		36.0	
5A55 injector – 117 BHP		34.0	
5A60 injector		37.0	41.0
5N45 injector	20.0		
N50 injector		31.0	
N65 injector		39.0	
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner	20.0	20.0	20.0
Clean air cleaner	12.0	12.0	12.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.5	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45–70	45–70	45–70
Minimum	35	35	35
Fuel spill (gpm) – min. at no load:			
.070″ restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–187	170–187	170–187
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	510		
Minimum – at 600 rpm	460		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

•3-53 "SILVER" TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm
Lubrication System		
Lubricating oil pressure (psi):		
Normal	40–60	40–60
Minimum for safe operation	30	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
5E50 injector	27.5	33
5E55 injector	32.5	38
5E60 injector	37.5	44
injector		
injector		
injector		
Air inlet restriction (inches water) – full load max.:		
Dirty air cleaner	20	20
Clean air cleaner	12	12
Crankcase pressure (inches water) – max.	2.8	3.0
Exhaust back pressure (inches mercury) – max.:		
Full load	2.5	3.0
Fuel System		
Fuel pressure at inlet manifold (psi)		
Normal with .070" restriction	45–70	45–70
Minimum	35	35
Fuel spill (gpm) – min. at no load:		
.070" restriction	0.6	0.6
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	170–187	170–187
Compression		
Compression pressure (psi at sea level):		
Average – new engine – at 600 rpm	470	470
Minimum – at 600 rpm	420	420

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

4–53 TURBOCHARGED ENGINES

	Marine 2500 rpm	Industrial 2500 rpm	Vehicle 2500 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40–60	40–60	40–60
Minimum for safe operation	32	36	36
†Lubricating oil temperature (deg. F) – Normal	205–240	200–235	200–235
Air System			
Air box pressure (inches mercury) –min. full load:			
At zero exhaust back pressure:			
5A55 injector		36.0	36.0
5A60 injector (Federal)		39.0	39.0
5A60 injector (California)			41.0
N65 injector		39.0	
N70 injector (clean ports)	31.5–38.5		
At maximum exhaust back pressure:			
5A55 injector		31.5	
5A60 injector (Federal)		34.5	
5A60 injector (California)			37.0
N65 injector		34.5	
N70 injector	29.6–36.6		
Air inlet restriction (inches water) – full load max.:			
Air silencer	20.0		
Air cleaner (dirty)		20.0	20.0
Air cleaner (clean)		12.0	12.0
Crankcase pressure (inches water) – max.	1.0	3.0	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.5	3.0	2.5
No load			1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45–70	45–70	45–70
Minimum	35	35	35
Fuel spill (gpm) – minimum at no load:			
.070″ restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	170–187	180–197
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	480	510	510
Minimum – at 600 rpm	430	460	460

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

•4–53 "SILVER" TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm
Lubrication System		
Lubricating oil pressure (psi):		
Normal	34–54	37–57
Minimum for safe operation	30	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
5C50 injector	28.7	36.0
5C55 injector	35.4	41.4
5C60 injector	40.0	45.5
At maximum exhaust back pressure:		
5C50 injector		
5C55 injector		
5C60 injector		
Air inlet restriction (inches water) – full load max.:		
Air cleaner (dirty)	20	20
Air cleaner (clean)	12	12
Crankcase pressure (inches water) – max.	2.8	3.0
Exhaust back pressure (inches mercury) – max.:		
Full load	2.5	3.0
Fuel System		
Fuel pressure at inlet manifold (psi)		
Normal with .070″ restriction	45–70	45–70
Minimum	35	35
Fuel spill (gpm) – min. at no load:		
.070″ restriction	0.6	0.6
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	170–187	170–187
Compression		
Compression pressure (psi at sea level):		
Average – new engine – at 600 rpm	470	470
Minimum – at 600 rpm	420	420

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–53 TURBOCHARGED ENGINES

	Marine 2800 rpm	Industrial 2500 rpm	Vehicle 2600 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40–60	40–60	40–60
Minimum for safe operation	32	36	36
†Lubricating oil temperature (deg. F) – Normal	205–235	200–235	200–235
Air System			
Air box pressure (inches mercury) –min. full load:			
At zero exhaust back pressure:			
5A50 injector (Federal)		34.0	36.5
5A50 injector (California)			38.0
5A55 injector		39.5	
5N65 injector	38.0		
N–70 injector	39.3		
At maximum exhaust back pressure:			
5A50 injector (Federal)		29.5	32.8
5A50 injector (California)			34.3
5A55 injector		35.0	
5N65 injector	33.5		
N–70 injector	47.3		
Air inlet restriction (inches water) – full load max.:			
Air silencer	20.0		
Air cleaner (dirty)		20.0	20.0
Air cleaner (clean)		12.0	12.0
Crankcase pressure (inches water) – max.	1.0	3.0	3.0
N–70 injector	2.8		
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	2.5	2.5
N–70 injector — Twin Turbo	2.5		
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45–70	45–70	45–70
Minimum	35	35	35
Fuel spill (gpm) – minimum at no load:			
.070″ restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	170–187	180–197
N–70 injector	170–185	—	—

	Marine 2800 rpm	Industrial 2500 rpm	Vehicle 2600 rpm
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	480	510	510
Minimum – at 600 rpm	430	460	460

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

•6-53 "SILVER" TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm
Lubrication System		
Lubricating oil pressure (psi):		
Normal	40–60	40–60
Minimum for safe operation	30	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
5C50 injector	29.1	36.1
5C55 injector	31.5	38.2
5C60 injector	40.5	47.1
At maximum exhaust back pressure:		
5C50 injector		
5C55 injector		
5C60 injector		
Air inlet restriction (inches water) – full load max.:		
Air cleaner (dirty)	20	20
Air cleaner (clean)	12	12
Crankcase pressure (inches water) – max.	3.0	3.0
Exhaust back pressure (inches mercury) – max.:		
Full load	2.5	2.5
Fuel System		
Fuel pressure at inlet manifold (psi)		
Normal with .070" restriction	45–70	45–70
Minimum	35	35
Fuel spill (gpm) – min. at no load:		
.070" restriction	0.6	0.6
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	170–187	170–187
Compression		
Compression pressure (psi at sea level):		
Average – new engine – at 600 rpm	470	470
Minimum – at 600 rpm	420	420

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V-53 "SILVER" TURBOCHARGED-INTERCOOLED ENGINES MARINE

	2800 rpm
Lubrication System	
Lubricating oil pressure (psi):	
Normal	40–60
Minimum for safe operation	32
†Lubricating oil temperature (deg. F) – Normal	200–250
Air System	
Air box pressure (inches mercury) – min. full load:	
At zero exhaust back pressure:	
7005 injector	62.2
Air inlet restriction (inches water) – full load max.:	
Air silencer	20.0
Crankcase pressure (inches water) – max.	4.0
Exhaust back pressure (inches mercury) – max.:	
Full load	2.5
Fuel System	
Fuel pressure at inlet manifold (psi)	
Normal with .070″ restriction	45–70
Minimum	35
Fuel spill (gpm) – min. at no load:	
.070″ restriction	1.05
Pump suction at inlet (inches mercury) – max.:	
Clean system	6.0
Dirty system	12.0
Cooling System	
Coolant temperature (deg. F) – Normal	167–187

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

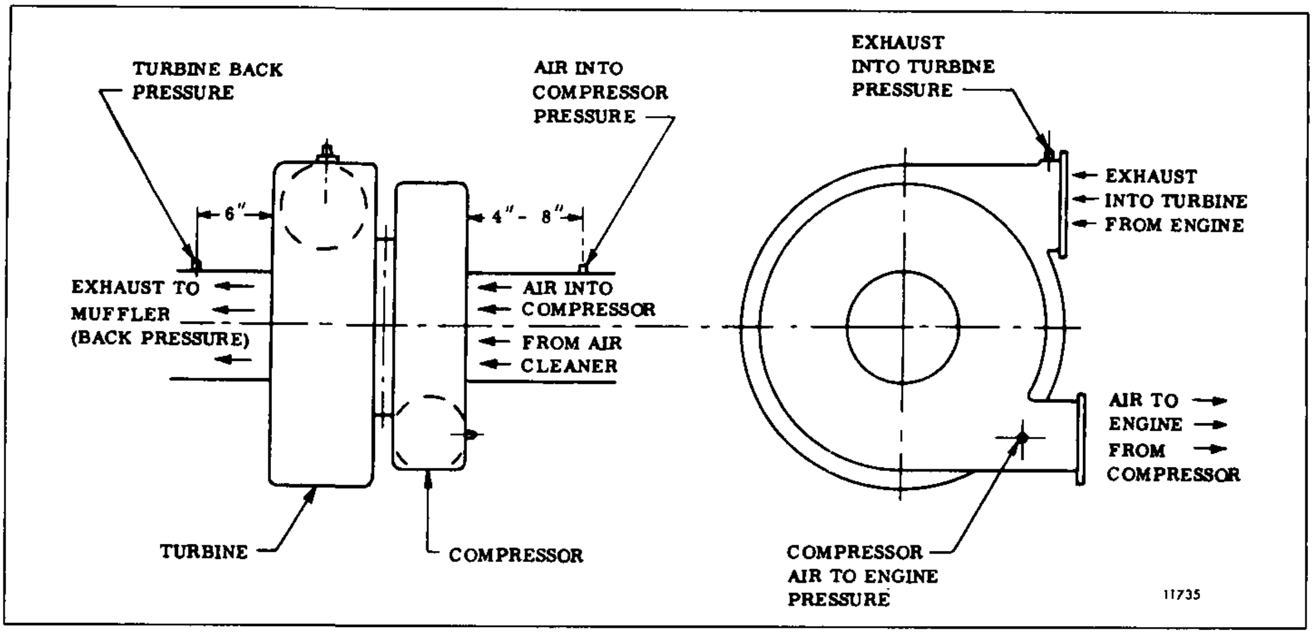


Fig. 1 – Points to Measure Intake and Exhaust Restriction

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run-In" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the technician to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (see Section 13.2) should be maintained throughout the Run-In.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F (6°C) higher than the water inlet temperature. Though a 10°F (6°C) rise across an engine is recommended, it has been found that a 15°F (8°C) temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the Run-In. However, if the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

NOTICE: Because of the wet cylinder liners in the Series 53 engine, the engine should be run-in on a closed (heat exchanger type) cooling system where the coolant can be treated with a rust inhibitor (refer to Section 13.3). Use of a good rust inhibitor in the coolant system during engine Run-In will prevent the rusting of the outside diameter of cylinder liners.

The Run-In Schedule is shown on page 2. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/cu m.), air temperature of 85°F (29°C) and 500 ft. elevation.

DYNAMOMETER TEST AND RUN-IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Basic Engine Run-In Schedule.* The following items are included on the basic engine: blower, fuel pump, water pump and governor. The fan and battery-charging alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report.* The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb-ft or N·m) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

Where:

BHP = brake horsepower

T = torque in lb-ft

RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page 3).

BASIC ENGINE RUN–IN SCHEDULE

Time Minutes	Speed RPM	Injector Size	ENGINE BRAKE HORSEPOWER									
			4-Valve Cylinder Head							2-Valve Cyl. Head		
			3-53		4-53		6V-53		8V-53	2-53	3-53	4-53
			NA	**T	NA	**T	NA	**T	NA	NA	NA	NA
10	600	All	0	0	0	0	0	0	0	0	0	0
◆30	2800	All		0		0		0				
10	1500	All	15	15	20	20	30	30	40	10	15	20
10	Rated Speed	5A50						112				
		5A55		58		78		117				
		5A60		63		84						
		N-65		65		87						
		5N65*						138				
10	Rated Speed	5A50						225				
		5A55		117		156		234				
		5A60		126		168						
		N-65		131		175						
		5N65*						275				
120	2000	All								40		
30	2200	All	64		87		130		175			
120	2200	All									62	93
30	2800	All	85		115		171		228			
Power Check	Rated Speed	All	Final BHP to be within ±5% of rated									

◆ Turbocharged engines *must* be operated within this RPM range for a full 30 minutes.
*5N65 rating for 6V-53T Marine engine only.
After run-in, *do not* run continuous full load during first 10 hours or 500 miles.
"O" BHP indicates running at no-load for specified time and speed.
**Prior to starting the engine, remove the turbocharger oil supply line at the turbocharger and add CLEAN engine oil to the turbocharger oil inlet to ensure pre-lubrication of the unit. Reconnect the oil line and idle the engine for at least one minute after starting and before increasing the engine speed.

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing or water outlet manifold.

e. Adaptor for connecting a pressure gage or water manometer to the crankcase.

f. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

h. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

i. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = psi x 27.7"
Inches of mercury = psi x 2.04"
Inches of water = kPa x 4.02"
Inches of mercury = kPa x 0.30"

NOTICE: Before starting the Run–In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

ENGINE TEST REPORT

Date ______ Unit Number ______

Repair Order Number ______ Model Number ______

A PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B BASIC ENGINE RUN-IN

TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUBE OIL PRESS.

C BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D INSPECTION AFTER BASIC RUN-IN

1. Tighten Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E FINAL RUN-IN

TIME		TOP RPM		BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L
START	STOP	NO LOAD	FULL LOAD				

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE		IDLE SPEED
				FULL LOAD	IDLE	

F INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd ______ Dynamometer Operator ______ Date ______

NOTE: Operator must initial each check and sign this report.

• Block Oil Filter Bypass Before Initial Start-Up and Dynamometer Test of Rebuilt Engines

Cold engine start-up causes the lubricating oil filter bypass valve to open until oil temperature increases. When an engine is rebuilt and then dynamometer tested, this bypass condition may result in the circulation of abrasive (harmful) debris introduced into the engine during rebuild.

To prevent unnecessary circulation of debris through the lube oil system, DDC recommends plugging the filter bypass before start-up and during basic engine run-in. This allows all the lube oil to flow through the filter(s), trapping contaminants. To plug the bypass, proceed as follows:

If the valve is secured by a retainer and screw, remove the spring and install a spacer of the appropriate length under the retainer (Fig. 1). The spacer must be long enough to contact the valve and keep it from moving during the dynamometer test. When the test is completed, *remove the spacer and reinstall the spring.* Then change the filter(s).

If the valve is secured by a plug, drill and tap a 1/4" – 20 hole in a filter bypass valve plug. Install a bolt long enough to contact the valve and keep it from opening and a nut to lock the bolt in position (Fig. 2). When the dynamometer test is completed, replace the modified plug with a standard plug and change the filter(s).

NOTICE: To avoid damaging the phenolic bypass valve, the bolt should be finger-tightened only and then secured in place with the lock nut. On filter adaptors with more than one bypass valve, install modified valve plugs in all valve openings before starting or dynamometer testing the engine.

DDC recommends bringing lube oil temperature up to at least 60°F (15.6°C) before starting the engine prior to testing. If the lube oil is too cold when the engine is started, the resistance to flow of the heavier oil may cause filter gasket leakage or bearing surface damage from inadequate oil film.

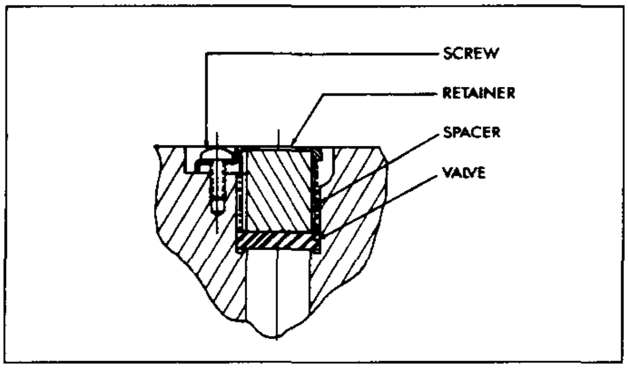


Fig. 1 – Bypass Valve with Spacer Installed

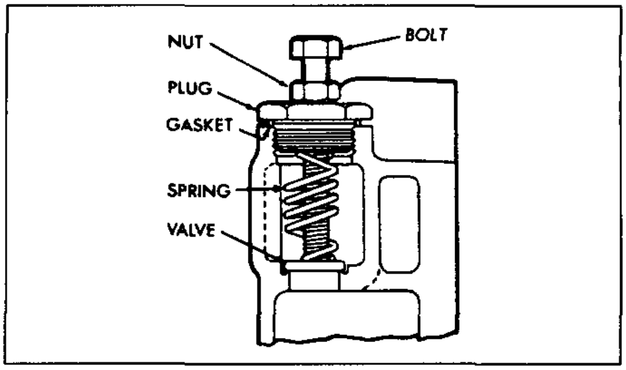


Fig. 2 – Bypass Valve with Modified Valve Plug Installed

Run-In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report.*

A. PRE-STARTING

1. Fill the lubrication system as outlined under *Lubrication System — Preparation for Starting Engine First Time* in Section 13.1.
2. Prime the fuel system as outlined under *Fuel System* — Preparation for Starting Engine First Time in Section 13.1.
3. preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.
4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing* in Section 14.2.
5. Preliminary governor adjustments must be made as outlined in Section 14.
6. Preliminary injector rack adjustment must be made (Section 14).

NOTICE: Prior to starting a turbocharged engine, remove the oil supply line at each turbocharger and add clean engine oil to the oil inlet to ensure pre-lubrication of the turbochargers. Reconnect the oil lines and idle the engine for at least one minute after starting and before increasing the speed.

B. BASIC ENGINE RUN–IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this Run–In will be a test of the workmanship of the technician who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also, inspect the exhaust system, air cleaner and air inlet piping to insure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 lb–ft (7 N·m) on the torque gage (or 10–15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the Test and Run–In, and to the *Basic Engine Run–In Schedule* which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also, refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full–load speed designated for the Run–In. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the Run–In.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Basic Engine Run–In Schedule.*

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the *Engine Test Report.*

Run the engine at each speed and rating for the length of time indicated in the *Basic Engine Run–In Schedule.* This is the Basic Run–In. During this time, engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN–IN INSPECTION

While the engine is undergoing the Basic Run–In, check each item indicated in Section "C" of the *Engine Test Report.* Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run–In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run–In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN–IN

The primary purpose of this inspection is to provide a fine engine tune–up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune–up procedure. Refer to Section 14.

E. FINAL RUN–IN

After all of the tests have been made and the *Engine Test Report* is completed through Section "D", the engine is ready for final test. This portion of the Test and Run–In procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm–up period of 10 minutes at the same speed and load used for warm–up in the Basic Run–In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run–In, the entire Basic Run–In must be repeated as though the Run–In and Test procedure were started anew.

All readings observed during the Final Run–In should fall within the range specified in the *Operating Conditions* in Section 13.2 and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine *water temperature* should be taken during the last portion of the Basic Run–In at full load. It should be recorded and should be within the specified range.

The *lubricating oil temperature* reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The *lubricating oil pressure* should be recorded in psi after being taken at engine speeds indicated in the *Operating Conditions,* Section 13.2.

The *fuel oil pressure* at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the Final Run–In.

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0–15 psi) or manometer (15–0–15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the *crankcase pressure* while the engine is operating at maximum Run–In speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run–In indicating that new rings are beginning to "seat–in".

Check the *air inlet restriction* with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing on naturally aspirated engines. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at a specific full–load engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of one of the turbochargers (see Chart at the end of Section 13.2). The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal *air intake vacuum* at various speeds (at no–load) and compare the results with the *Engine Operating Conditions* in Section 13.2. Record these readings on the *Engine Test Report.*

Check the *exhaust back pressure* (except turbocharged engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the *Maximum Exhaust Back Pressure* for the engine (refer to Section 13.2).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full–load and no–load speeds.

Refer to the *Final Engine Run–In Schedule* and determine the maximum rated brake horsepower and the full–load speed to be used during the Final Run–In. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time by following the prescribed procedure. The engine should be run at this speed and load for 1/2 hour. While making the Final Run–In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no–load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run–In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run–In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run–In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run–In is complete.

F. INSPECTION AFTER FINAL RUN–IN

After the Final Run–In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in Section 15.3 and adding a rust inhibitor into the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

> **NOTICE:** A rust inhibitor in the coolant system of a Series 53 engine is particularly important because of the wet cylinder liners. Omission of a rust inhibitor will cause rusting of the outside diameter of the cylinder liners and interference with liner heat transfer.

LUBRICATING OIL, FUEL OIL AND FILTER RECOMMENDATIONS

Selection of the proper quality of fuel and lubricating oil is important to achieve the long and trouble–free service for which Detroit Diesel engines are designed. Conversely, operation with improper fuels and lubricants can cause problems. The manufacturer's warranty applicable to Detroit Diesel engines provides, in part, that warranty shall not apply to any engine which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow manufacturer's fuel or lubricating recommendations may not be covered by the warranty.

A requirement of Detroit Diesel Corporation's extended warranty program (Power Protection Plan) is that the customer use the lubricants, fuels and filters recommended in this publication.

It is Detroit Diesel's policy to build engines which will operate satisfactorily with fuels and lubricants available in the commercial market. However, not all fuels and lubricants are adequate. Product selection should be made based on these recommendations and in consultation with a reliable supplier who understands the equipment and its application.

LUBRICATING OIL

Engine service life depends upon selecting the proper lubricating oil and maintaining proper oil drain and filter change intervals.

LUBRICANT SELECTION

There are hundreds of commercial oils marketed today, but labeling terminology differs among suppliers and can be confusing. Some marketers may claim that their lubricant is suitable for all makes of diesel engines and may list engine makes and types, including Detroit Diesel, on their containers. Such claims by themselves are insufficient as a method of lubricant selection for Detroit Diesel engines.

The proper lubricating oil for all Detroit Diesel engines is selected based on SAE Viscosity Grade and API (American Petroleum Institute) Service Designation. Both of these properties are displayed on oil containers in the API symbol. In addition, military specifications may be used for selecting engine lubricants. Mil–L–2104D represents the most current military specification for diesel lubricants and the only one recommended for Detroit Diesel engines. For two–cycle Detroit Diesel engines, the proper lubricant must also possess a sulfated ash content below 1.0% mass. Refer to the following specific recommendations.

TWO–CYCLE ENGINES
Detroit Diesel Series 53, 71, 92, 149

LUBRICANT RECOMMENDATION

API Symbol:

SAE Viscosity Grade: 40
API Classification: CD–II
Military Spec.: Mil–L–2104D
Sulfated Ash: less than 1.0%

This is the only engine oil recommended for Detroit Diesel two–cycle engines. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

A more detailed description of each of these selection criteria may be found in a further section of this publication. Certain engine operating conditions may require exceptions to this recommendation. They are as follows:

1. For continuous high temperature operation (over 100°F ambient or 200°F Coolant Out) the use of an SAE grade 50 lubricant in all series two–cycle DDC engines is recommended.

2. At ambient temperatures below freezing where starting aids are not available or at very cold temperatures (0 to –25°F), the use of multiviscosity grade 15W–40 or monograde SAE 30 lubricants will improve startability. **Exception: Do not use these lubricants in two–cycle marine engines or DDC series 149 engines under any circumstances.**

3. The API category CD–II is relatively new and may not be fully in use at the time of this publication. API category CD may be used provided the recommended military specification is satisfied. Oils with API designation CE are not recommended in DDC two–cycle engines unless accompanied by CD–II.

4. When the use of high sulfur fuel is unavoidable, lubricants with a Total Base Number exceeding 10 are recommended. Such a lubricant may have a Sulfated Ash content above 1.0% mass. High sulfur fuels require modification to oil drain intervals. For further information refer to that section of this publication.

FOUR–CYCLE ENGINES
Detroit Diesel Series 60 and 8.2L

LUBRICANT RECOMMENDATION

API Symbol:

SAE Viscosity Grade: 15W–40
API Classification: CE
Military Spec.: Mil–L–2104D

This is the only engine oil recommended for Detroit Diesel Series 60 and 8.2L engines. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

When the use of high sulfur fuel is unavoidable, lubricants with a TBN exceeding 10 are recommended. High sulfur fuels require modification to oil drain intervals. For further information refer to that section of this publication.

LUBRICATING OIL SELECTION CRITERIA

SAE VISCOSITY GRADE

Viscosity is a measure of an oil's ability to flow at various temperatures. The SAE Viscosity Grade system is defined in SAE Standard J300 which designates a viscosity range with a grade number. Lubricants with two grade numbers separated by a "W" are classified as multigrade, while those with a single number are monograde. The higher the number the higher the viscosity.

API SERVICE CLASSIFICATION

The American Petroleum Institute has established a means of classifying lubricant performance suitable for different types of engines and types of service. The higher performance or quality API classifications for diesel engines include CD, CE (for four–cycle diesel engines) and CD–II (for two–cycle diesel engines). Detroit Diesel does not recommend the use of the older and lower performance classifications such as CC, CB and CA.

Multiple API Service Classifications such as "API SERVICE CD, CE" or "API SERVICE CE/CD–II" are frequently listed. Additional classifications not listed here may also be included. It is important that the DDC recommended classification be among those listed.

API SYMBOL

Lubricant marketers have adopted a uniform method of displaying the SAE viscosity grade and API service classification information on product containers and in product literature. The three segment "donut" contains the SAE grade number in the center, and the API service in the top segment. The lower segment is used to designate energy conserving status for gasoline engine use and has no significance for diesel engine use.

MILITARY SPECIFICATION

U.S. Military specifications are another means of classifying the performance of lubricants. As with the API system, lubricants must meet performance criteria before approval is given. The essential difference, however, is that lubricants meeting military specifications, particularly those possessing Qualified Products Listing (QPL) Numbers, have been reviewed by a committee consisting of engine manufacturers, including Detroit Diesel.

Military Specification Mil–L–2104D represents the current specification for heavy–duty diesel engines and the *only one recommended* by Detroit Diesel Corporation.

SULFATED ASH AND TOTAL BASE NUMBER

This is a lubricant property obtained by a laboratory test (ASTM D874) to determine potential for the formation of metallic ash. The ash residue is related to the oil's additive composition and is significant in predicting lubricants which may cause valve distress under certain operating conditions. Sulfated ash is related to Total Base Number (TBN), also a laboratory test (ASTM D2896) which measures an oil's ability to neutralize acids. As TBN increases, sulfated ash also increases to where lubricants with TBNs above 10 will likely have sulfated ash contents above 1.0% mass.

Total Base Number is important to deposit control in four–cycle diesel engines and to neutralize the effects of high sulfur fuel in all diesel engines. In general, Detroit Diesel recommends lubricants with sulfated ash contents below 1.0% mass and TBNs between 7 and 10 for all Series engines operating on low sulfur fuel.

UNIVERSAL OILS

Universal oils are designed for use in both gasoline and diesel engines and provide an operational convenience in mixed fuel engine fleets. These products are identified with combination API category designations such as SF/CD or SG/CE. Although such products can be used in Detroit Diesel engines (provided they satisfy all DDC requirements), their use is not as desirable as lubricants formulated specifically for diesel engines, and bearing only the API CD–II or CE designations.

SYNTHETIC OILS

Synthetic oils may be used in Detroit Diesel engines provided they meet the viscosity, performance classification and chemical recommendations listed for non–synthetic lubricants. Product information about synthetic oils should be reviewed carefully since these lubricants are often claimed to be of monograde viscosity. Their use does not permit extension of recommended oil drain intervals.

MARINE LUBRICANTS, RAILROAD DIESEL LUBRICANTS

The petroleum industry markets specialty lubricants for use in diesel engines designed specifically for marine propulsion or railroad locomotive use. These lubricants take into consideration the unique environments and operational characteristics of this type of duty, and consequently, they are formulated quite differently from the types of lubricants recommended by Detroit Diesel. Although in some cases they may be suitable in Detroit Diesel engines, they should not be used without specific consultation with your Detroit Diesel distributor or regional office and the lubricant supplier.

USE OF SUPPLEMENTAL ADDITIVES

Lubricants meeting the Detroit Diesel recommendations outlined in this publication already contain a balanced additive treatment. The use of supplemental additives, such as break–in oils, top oils, graphitizers, and friction–reducing compounds, is generally unnecessary and can even be harmful. Never use a lubricant supplement to “fix” a mechanical problem, and be cautious of products purporting to prevent one. The best approach is to follow DDC’s lubricant recommendations.

EVIDENCE OF SATISFACTORY LUBRICANT PERFORMANCE

These recommendations are intended to provide a guideline for lubricating oil selection based on favorable service history in typical applications of Detroit Diesel engines. Specific situations may warrant consideration of a lubricant that does not fit these guidelines. Such a lubricant may perform satisfactorily in certain circumstances, and be inappropriate for others.

For such products, evidence of satisfactory performance should be obtained from the oil supplier on the specific lube oil blend being considered and compared with the performance of a DDC recommended lubricant as reference. Comparative performance evidence would include stationary engine tests and field testing in a similar application and severity.

The type of field test used by the oil supplier depends on the series engine in which the candidate oil will be used and the service application. The candidate test oil engines should all operate for the mileage/hours indicated in the table below. Any serious mechanical problems should be recorded. At the conclusion of the test, the engines should be disassembled and quantitatively compared with reference oil engines for:

- Ring conditions (broken, stuck and wear)
- Cylinder liner and piston skirt scuffing
- Exhaust valve face and seat deposits and distress
- Piston pin and slipper bushing wear
- Piston ring land deposits
- Overall valve train and bearing wear

Several stationary engine tests have been designed by and utilized by Detroit Diesel for evaluation of lubricants. These tests include:

100 Hour Series 92 Accelerated Engine Test
– evaluates liners, rings and slipper bushings

Series 71 Valve Guttering Test
– evaluates effects of high ash on valve distress

100 Hour Series 60 Truck Cycle Test
– evaluates deposit and ring sticking

240 Hour 6V53T Endurance Test (FTM 355)
– evaluates liner and ring wear (used for CD–II)

LUBRICATING OIL FIELD TESTING GUIDELINES

ENGINE SERIES	SERVICE APPLICATION	TEST DURATION	NO. ENGINES ON CANDIDATE TEST OIL	NO. ENGINES ON REFERENCE BASELINE OIL
53	Pickup & Delivery	50,000 Miles	5	5
60, 71, 92	Highway Truck, GVW 78,000 lbs	200,000 Miles	5	5
149	Off–Road 120 Ton Rear Dump	10,000 Hours	3	3

Although stationary engine testing provides important lubricant performance evaluation, it should be considered secondary to a properly conducted field test evaluation.

Upon completion of the field and stationary testing of products which meet or exceed the performance of lubricants recommended in this publication, Detroit Diesel will issue a written approval for their use in the application field tested. Such approval will be limited to the specific formulation (identical basestock and additive treatment) in which the testing was conducted.

OIL CHANGE INTERVALS

During use, engine lubricating oil undergoes deterioration from combustion by-products and contamination. For this reason, regular oil drain intervals are necessary. These intervals however, may vary in length depending upon engine operation, fuel quality, and lubricant quality. The oil drain interval may be established on recommendations of a Detroit Diesel Oil Analysis Program until the most practical oil change interval has been determined. Under no circumstances, however, should the drain intervals in the chart be exceeded. Refer to the "Used Lubricating Oil Analysis" section of this publication for more information. All engine oil filters should be changed when the lube oil is changed.

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS (Normal Operation)

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL
Highway Truck	60, 71 & 92	20,000 Miles (32,000 kM)
City Transit Coaches	53, 71 & 92	6,000 Miles (9,600 kM)
Pick-up & Delivery, Stop & Go, Short Trip	53, 71, 92	12,000 Miles (19,000 kM)
	8.2L	6,000 Miles (9,600 kM)
Industrial, Agricultural and Marine	149NA	500 Hrs. or 1 Yr.
	149T	300 Hrs. or 1 Yr.
	53, 60, 71, 92 & 8.2L	150 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	500 Hrs. or 1 Mo.
Standby	53, 71, 92, 149 & 8.2L	150 Hrs. or 1 Yr.

OIL CHANGE INTERVALS WHEN USING HIGH SULFUR FUEL

When the continuous use of high sulfur fuel (greater than 0.5%) is unavoidable, lubricant selection and oil drain interval must be modified. A lubricant with a Total Base Number (TBN per ASTM D 2896) above 10 is recommended. It is likely that such a lubricant will also exhibit a sulfated ash above 1.0%. The proper oil drain interval must be determined by oil analysis when operating on high sulfur fuel. A reduction in TBN (D 2896) to one third of the initial value provides a general drain interval guideline.

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS

FUEL SULFUR 0.5% TO 1.0%
Use a lubricant with TBN (ASTM D 2896) 10 to 30

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL 10-19 TBN	20-30 TBN
Highway Truck	60, 71 & 92	15,000 Mi. (24,000 kM)	20,000 Mi. (32,000 kM)
City Transit Coaches	53, 71 & 92	4,000 Mi. (6,400 kM)	6,000 Mi. (9,600 kM)
Pick-up & Delivery Stop & Go, Short Trip	53, 71 & 92	8,000 Mi. (12,500 kM)	12,000 Mi. (20,000 kM)
	8.2L	4,000 Mi. (6,400 kM)	6,000 Mi. (9,600 kM)
Industrial, Agricultural and Marine	149NA	300 Hrs.	500 Hrs.
	149T	200 Hrs.	300 Hrs.
		(or 1 Yr. Maximum)	
	53, 60, 71, 92 & 8.2L	100 Hrs.	150 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	300 Hrs.	500 Hrs.
		(or 1 Mo. Maximum)	
Standby	53, 71, 92, 149 & 8.2L	100 Hrs.	150 Hrs.
		(or 1 Yr. Maximum)	

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS

FUEL SULFUR ABOVE 1.0%
Use a lubricant with TBN (ASTM D 2896) 10 to 30

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL 10-19 TBN	20-30 TBN
Highway Truck	60, 71 & 92	7,500 Mi. (12,000 kM)	15,000 Mi. (24,000 kM)
City Transit Coaches	*53, 71 & 92*	*2,000 Mi.* (3,000 kM)	*4,000 Mi.* (6,400 kM)
Pick-up & Delivery Stop & Go, Short Trip	53, 71 & 92	4,000 Mi. (6,500 kM)	8,000 Mi. (12,500 kM)
	8.2L	2,000 Mi. (3,000 kM)	4,000 Mi. (6,400 kM)
Industrial, Agricultural and Marine	149NA	150 Hrs.	300 Hrs.
	149T	100 Hrs.	200 Hrs.
		(or 6 Mos. Maximum)	
	53, 60, 71, 92 & 8.2L	*50 Hrs.*	*100 Hrs.*
Stationary Units Full Time	53, 71, 92 & 149	150 Hrs.	300 Hrs.
Standby	53, 71, 92, 149 & 8.2L	50 Hrs.	100 Hrs.
		(or 6 Mos. Maximum)	

USED LUBRICATING OIL ANALYSIS

A used lubricating oil analysis program such as the Detroit Diesel Oil Analysis Program is recommended for the monitoring of crankcase oil in all engines. Since an oil analysis indicates the condition of the engine, not the lubricating oil, it should not be used to extend oil drain intervals. The oil should be changed immediately if any contamination is present in concentrations exceeding the warning limits shown in the table. It should not however, be concluded that the engine is worn out based on *a single* measurement that exceeds the warning level. Imminent engine wearout can only be determined through a *continuous* oil analysis program wherein the change in data or deviation from baseline data can be used to interpret condition of engine parts.

Characteristics relating to lubricating oil dilution should trigger corrective action to identify and fix the source(s).

Confirmation of the need for engine overhaul should be based on operational data (increasing oil consumption and crankcase pressure, for example) and physical inspection of parts.

USED LUBRICATING OIL ANALYSIS WARNING LIMITS

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown.

WARNING LIMITS

	ASTM Designation	Two Cycle		Four Cycle
		53, 71, 92	149	60, 8.2
Pentane Insolubles Mass % Max.	D 893	1.0	1.0	1.0
Carbon (Soot) Content, TGA Mass % Max.	E 1131	0.8		1.5
Viscosity at 40°c St % Max. Increase % Max. Decrease	D 445 & D 2161	40.0 15.0	40.0 15.0	40.0 15.0
Total Base Number (TBN) Min. Min.	D 664 D 2986	1.0 2.0	1.0 2.0	1.0 2.0
Water Content (dilution) Vol. % Max.	D 95	0.30	0.30	0.30
Flash Point °C Reduction Max.	D 92	40.0	40.0	40.0
Fuel Dilution Vol. % Max.	*	2.5	1.0	2.5
Glycol Dilution PPM Max.	D 2982	1000	1000	1000
Iron Content PPM Fe Max.	**	150	35	60=150 8.2=250
Copper Content PPM Cu Max.	**	25	25	60=90 8.2=30
Sodium Content PPM Na Over Baseline Max.	**	50	50	50
Boron Content PPM B Over Baseline Max.	**	20	20	20

* No ASTM Designation
** Elemental Analysis are conducted using either emission or atomic absorption spectroscopy. Neither method has an ASTM designation.

FUEL OIL

QUALITY AND SELECTION

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. DDC engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (grades 1–D and 2–D) have provided satisfactory performance. The ASTM D 975 specification however does not in itself adequately define the fuel characteristics necessary for assurance of fuel quality. The properties listed in the Fuel Oil Selection Chart have provided optimum engine performance.

FUEL OIL SELECTION CHART

General Fuel Classification	ASTM Test	No. 1 ASTM 1–D	No. 2* ASTM 2–D
Gravity, °API #	D 287	40–44	33–37
Flash Point Min. °F (°C)	D 93	100 (38)	125 (52)
Viscosity, Kinematic cST @ 100°F (40°C)	D 445	1.3–2.4	1.9–4.1
Cloud Point °F #	D 2500	See Note 1	See Note 1
Sulfur Content wt%, Max.	D 129	0.5	0.5
Carbon Residue on 10%, wt%, Max.	D 524	0.15	0.35
Accelerated Stability Total Insolubles mg/100 ml, Max. #	D 2274	1.5	1.5
Ash, wt%, Max.	D 482	0.01	0.01
Cetane Number, Min. +	D 613	45	45
Distillation Temperature, °F (°C)	D 86		
IBP, Typical #		350 (177)	375 (191)
10% Typical #		385 (196)	430 (221)
50% Typical #		425 (218)	510 (256)
90% +		500 (260) Max.	625 (329) Max.
End Point #		550 (288) Max.	675 (357) Max.
Water & Sediment %, Max.	D 1796	0.05	0.05

Not specified in ASTM D 975
+ Differs from ASTM D 975
* No. 1 diesel fuel is recommended for use in city coach engine models. No. 2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

Note 1: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

Note 2: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of 1–D fuel is recommended. Number 1–D fuels should also be considered when operating continuously at altitudes above 5000 ft.

FUEL OIL SELECTION CRITERIA

DISTILLATION

The boiling range is a very important property in consideration of diesel fuel quality. The determination of boiling range is made using ASTM Test Method D 86. Many specifications contain a partial listing of the distillation results, ie., Distillation Temperature At 90% Recovered. Many diesel fuels are blended products which may contain constituents with boiling ranges much different than the majority of the fuel composition. The full boiling range as shown in the Fuel Oil Selection Chart should be used for proper selection.

FINAL BOILING POINT

Fuel can be burned in an engine only after it has been vaporized. The temperature at which fuel is completely vaporized is described as the End point Temperature in ASTM D 86 Distillation Test Method. This temperature must be low enough to permit complete vaporization at combustion chamber temperatures. The combustion chamber temperature depends on ambient temperature, engine speed and load. Poor vaporization is more apt to occur during severe cold weather, prolonged idling, and/or light load operation. Therefore engines operating under these conditions should utilize fuels with lower distillation end point temperatures.

COMPLETELY DISTILLED FLUID

Fuel selected should be completely distilled material. That is, the fuel should exhibit no less than 98% recovery when subjected to the ASTM D 86 Distillation Test Method.

CETANE NUMBER

Cetane Number is mistakenly used to indicate fuel quality. However, Cetane Number is most useful in predicting engine startup. A high Cetane Number should not be considered alone when evaluating fuel quality. Other properties such as end point distillation temperature and carbon residue should also be considered. Calculated Cetane Index is sometimes reported instead of Cetane Number. Cetane Index is an empirical property determined through the use of a mathematical equation whereas Cetane Number is determined through an engine test.

FUEL STABILITY

Diesel Fuel oxidizes in the presence of air and water, particularly if the fuel contains cracked products which are relatively unstable. The oxidation of fuel can result in the formation of undesirable gums and sediment. Such undesirable products can cause filter plugging, combustion chamber deposit formation and gumming or lacquering of injection system components with re^ultant sticking or wear.

ASTM Test Method D 2274 measures diesel fuel oxidative stability. Although the results of the test may vary with actual field storage, it does measure characteristics which will effect fuel storage stability for periods up to 12 months.

FUEL SULFUR CONTENT

The sulfur content of the fuel should be as low as possible to avoid premature wear and excessive deposit formation. Fuel containing no more than 0.5% sulfur are recommended. If the use of fuels with sulfur contents above 0.5% are unavoidable, lube oil drain intervals and lubricant selection need to be changed. Detroit Diesel recommends that the Total Base Number (TBN D 2896) of the lubricant be monitored and the oil drain interval be reduced.

FUEL OPERATING TEMPERATURE AND VISCOSITY

Since Diesel Fuel provides cooling of the injection system, the temperature of the fuel may vary considerably due to the ambient temperature, engine operating temperature, and the amount of fuel remaining in the tank. As fuel temperature increases, the fuel viscosity and therfore the lubrication capabilities of the fuel diminish. Maintaining proper fuel temperatures in combination with selection of fuels with the viscosity ranges shown in the Fuel Oil Selection Chart will assure proper injection system functioning.

DIESEL FUEL STORAGE

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, and sludge; and cleaned if contaminated. Diesel fuel tanks can be made of aluminum, monel stainless steel, black iron, welded steel or reinforced (non–reactive) plastic.

> **NOTICE:** Galvanized steel or sheet metal tanks and galvanized pipes or fittings should never be used in any diesel fuel storage, delivery or fuel system. The fuel oil will react chemically with the zinc coating, forming a compound which can clog the filters and can cause engine damage.

FUEL ADDITIVES

Detroit Diesel engines operate satisfactorily on a wide range of diesel fuels without the addition of supplemental additives. Such additives increase operating costs without providing benefit.

Fuel additives specifically NOT recommended include:

- Used Lubricating Oil
- Gasoline

Detroit Diesel does NOT recommend the use of drained lubricating oil or gasoline in diesel fuel. Furthermore Detroit Diesel Corporation will not be responsible for any detrimental effects which it determines resulted form this practice.

Some fuel additives provide temporary benefits but do not replace good fuel handling practices. Such additives are helpful when water contamination is suspected:

- Isopropyl Alcohol—1 pint per 125 gallons of fuel for winter freeze up protection.
- Biocide—For treatment of microbe growth or black "slime". Follow manufacturers' instructions for treatment.

Other fuel additives are of questionable benefit. These include a variety of independently marketed products which claim to be:

- Cetane Improvers
- Combustion Improvers
- Cold Weather Flow Improvers

These products should be accompanied with performance data supporting their merit. It is not the policy of Detroit Diesel Corporation to approve or endorse such products.

FILTER RECOMMENDATIONS

Filters make up an integral part of fuel and lubricating oil systems. Proper filter selection and maintenence are important to satisfactory engine operation and service life. Filters should be utilized for maintaining a clean system, not for cleaning up a contaminated system.

FUEL FILTER RECOMMENDATION
Regular Service

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Primary	30	—	AC Spark Plug Div. GM	T552 T553 T541 T632 T915 T936 T958
Secondary	12	—	AC Spark Plug Div. GM	TP509 TP540X TP624 TP916 TP928 TP959

FUEL FILTER RECOMMENDATION
Severe Duty Service

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Primary	—	—	Racor	B32002
Secondary	3	200	Pall Corp.	Head HH7400A12UPRBP Element HC7400SUP-4H
Secondary *(Alternate)*	5	—	AC Spark Plug	TP916L TP928L TP959L

LUBRICATING OIL FILTER RECOMMENDATION
Series 53

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	12	75	AC Spark Plug Div. GM	PF911L P/N 25013192

COOLANT SPECIFICATIONS

COOLANT REQUIREMENTS

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. In general, water containing various materials in solution is used for this purpose.

The water/ethylene glycol/inhibitor coolant mixture used in Detroit Diesel engines must meet the following basic requirements:

- Provide for adequate heat transfer.
- Provide a corrosion–resistant environment within the cooling system.
- Prevent formation of scale or sludge deposits in the cooling system.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze and boil–over protection.

WATER

Water, whether of drinking quality or not, can produce a corrosive environment in the cooling system, and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, inhibitors *must* be added to control corrosion and scale deposits.

Chlorides, sulfates, magnesium, and calcium are among the materials which make up dissolved solids and may cause scale deposits, sludge deposits, corrosion, or a combination of these. Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium salts broadly classified as carbonates) causes deposits of scale. Water within the limits specified in Table A–1 is satisfactory as an engine coolant when properly inhibited. The procedure for evaluating water intended for use in a coolant solution is shown in Table A–2. Use of distilled water is ideal.

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

TABLE A–1

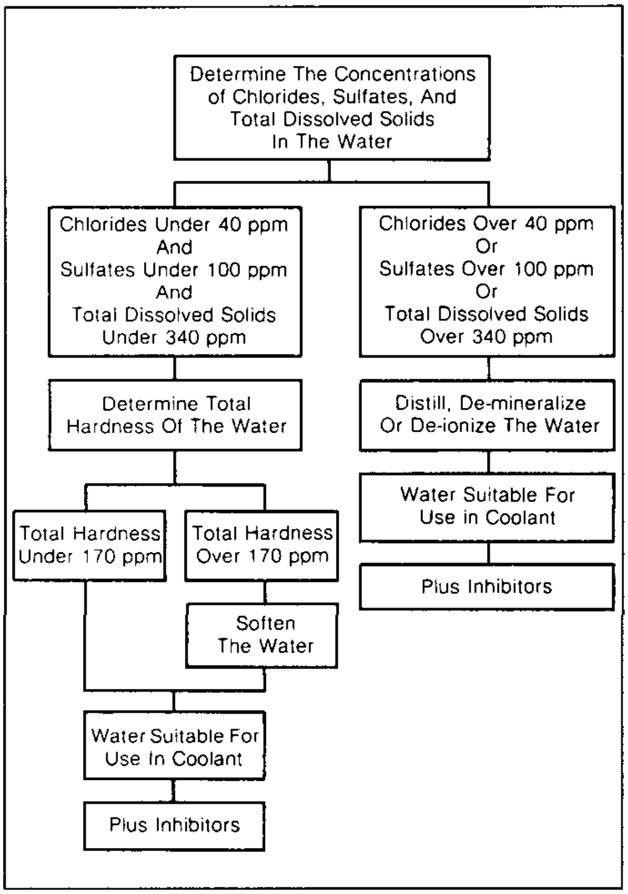


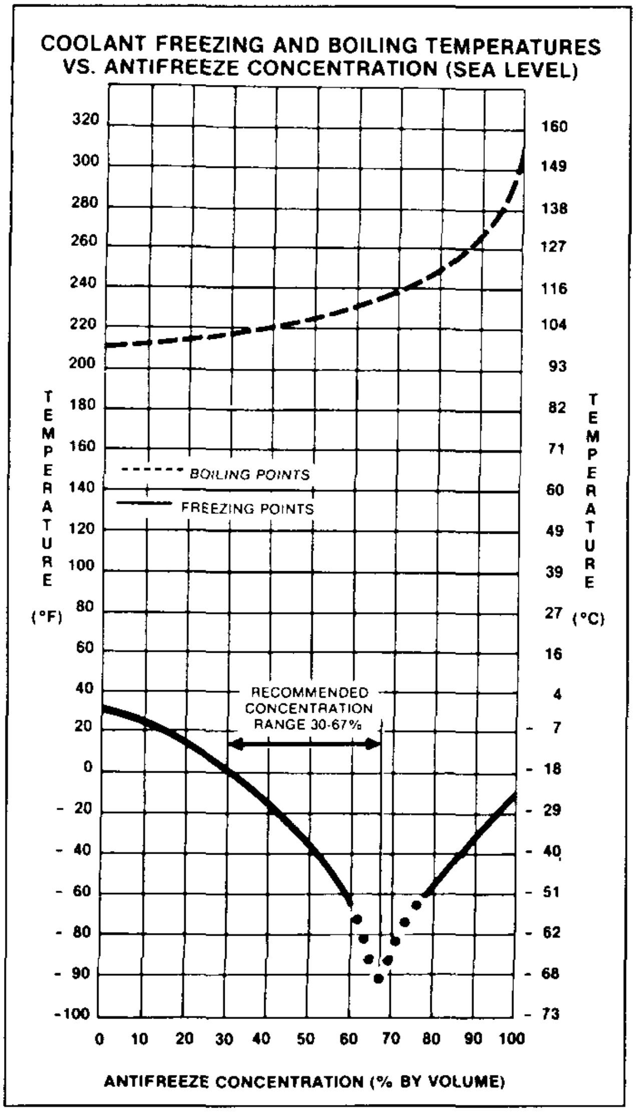
TABLE A–2

ANTIFREEZE

Use an ethylene glycol antifreeze that meets the GM 6038–M formulation, which limits silicate to 0.15% maximum, or an equivalent formulation meeting the 0.15% maximum silicate and GM 1899–M perfomance requirements. Ethylene glycol–base antifreeze meeting ASTM D 3306 requirements is also acceptable for use in Detroit Diesel engines.

A 50% antifreeze solution is normally used as a factory fill. Concentrations over 67% are not recommended because of poor heat transfer capability, adverse freeze protection and possible silicate drop–out. Concentrations below 30% offer little freeze, boil–over or corrosion protection.

Although most antifreezes contain inhibitor packages, all DDC and Perkins engines (except Perkins 500 Series) require supplemental inhibitors be added to the cooling system after an intial fill and maintained at proper protection level.



Antifreeze solution should be used year–round to provide freeze and boil–over protection as well as a stable environment for seals and hoses.

Only non–chromate inhibitors should be used with antifreeze solutions.

Coolant concentrate must be checked periodically at each oil change (600 hours or 20,000 miles maximum). Adjust concentration, if not at the proper protection level.

Pre–mix antifreeze/water makeup solution at the proper concentration before adding to the cooling system. This should prevent over– or under–coolant concentration problems.

Methyl alcohol–based antifreeze is not recommended for use in DDC engines because of its effect on the non–metallic components of the cooling system and its low boiling point. Methoxy propanol–based antifreeze is also not recommended for DDC engines because it is not compatible with fluoroelastomer seals found in the cooling system.

A cooling system properly maintained and protected with supplemental inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the antifreeze must be drained, discarded in an appropriate manner, and the cooling system thoroughly cleaned. Inspect all components that make up the cooling system and make necessary repairs at this time. Refill the cooling system with a recommended ethylene glycol–base antifreeze and water solution in the required concentration (see graph). Add required inhibitors. After filling, run engine until thermostat(s) open and top off to recommended *full* level. Reinstall fill/pressure cap.

INHIBITOR

The importance of a properly inhibited coolant cannot be overemphasized. A coolant which has insufficient inhibitors, the wrong inhibitors, or no inhibitors at all invites the formation of rust, scale, sludge and mineral deposits within the cooling system. These deposits can cause water pump seal wear and coat the walls of the cylinder block, liners, and coolant passages. Heat transfer rate is reduced as the deposits build up. An engine affected in this manner can cause an overheating condition, resulting in liner scuffing, scoring, piston seizure and cylinder head cracking. This may occur quickly or over a long period of time, depending on the location and amount of deposits.

An improperly inhibited coolant can become corrosive enough to "eat away" coolant passages and seal ring grooves and cause coolant leaks to develop. If the coolant leak is internal and accumulates on top of a piston, a hydrostatic look can occur. This can result in a bent connecting rod.

Insufficiently inhibited coolant can also contribute to *cavitation erosion.* Cavitation erosion is caused by the collapse of bubbles (vapor pockets) against the surfaces of various engine coolant passages. The collapsing bubble forms a pin point of very high pressure. Over a period of time these collapsing bubbles can wear (erode) away internal engine surfaces. Components such as fresh water pump impellers, cylinder liners, and blocks are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy, and holes can develop completely through them.

INHIBITOR SYSTEMS

An inhibitor system is a combination of chemical componds which provide corrosion protection, pH control, water–softening ability and cavitation suppresion. These systems are available in various forms, such as coolant filter elements, liquid and dry inhibitor additive packages, and as integral parts of antifreeze.

A corrosion inhibitor is a water–soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosive inhibitors are borates, nitrites, nitrates, chromates and soluble oil.

Chromates and soluble oils are not recommended as corrosion inhibitors for DDC engines.

- pH control chemicals are used to maintain an acid–free solution.
- Water–softening chemicals deter formation of mineral deposits.
- Cavitation suppression chemicals minimize the fomation of vapor pockets, preventing erosion of cooling system surfaces.

It is imperative that a supplemental inhibitor be added to the coolant on all DDC and Perkins engines after an initial fill and maintained at proper protection level.

NON–CHROMATES

Non–chromate inhibitor (borates, nitites, nitrates, etc.) systems are recommended for use with DDC engines. These systems can be used with either water or water–and–antifreeze solutions and provide corrosion protection, pH control, and water softening. Most non–chromate inhibitor systems offer the additional advantage of a simple on–site test to determine protection level. Since they are added directly to the coolant, no additional hardware or plumbing is required.

All inhibitors become depleted through normal operation, and additional inhibitor must be added to the coolant as required to maintain original strength levels.

NOTICE: Overinhibiting antifreeze solutions can cause silicate dropout. Always follow the manufacturer's recommendations on usage and handling.

SOLUBLE OIL

Soluble oils are not recommended for use in DDC engine cooling systems. A small amount of oil concentration has an adverse affect on heat transfer capabilities. For example, a 1.25% concentration of soluble oil in the cooling sytem increases fire deck temperature 6%, while a 2.50% concentration raises fire deck temperature 15%.

CHROMATES

Chromate inhibitors are not recommended for use in DDC engine cooling systems. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate and causing engine overheating. Cooling systems (engine included) operated with chromate–inhibited coolant must be chemically cleaned and flushed with plain water prior to refilling with a recommended coolant mixture. A commercial heavy–duty descaler should be used in accordance with the manufacture's recommendation for this purpose.

COOLANT FILTER ELEMENT

Replaceable elements are available with various chemical inhibitor systems. There are two types of filters containing supplemental coolant additives (SCA's). One is a pre–charge which must be used at the time of initial cooling system fill. The second is a maintenance filter which is used at each service interval. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed with coolant filters using magnesium lower support plates. The coolant solution attacks the plate, allowing dissolved magnesium to be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate is recommended to prevent these deposits.

High chloride coolants have a detrimental effect on the water–softening capabilities of systems using ion–exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by the regenerative process caused by high chloride–content solutions.

Change coolant filters at regular intervals per manufacturer's recommendation.

INHIBITOR TESTING PROCEDURES

Test kits and test strips are commercially available to check engine coolant for inhibitor strength. Coolants should be tested at each oil change (600 hours or 20,000 miles maximum) to ensure that the inhibitor levels are maintained within the following ranges for two commonly available inhibitor systems:

SUPPLEMENTAL COOLANT ADDITIVE VALUES WITH GM 6038–M/ASTM D–3306 ANTIFREEZE

	Nitrate/ Borate System		Phosphate/ Molybdate System	
	Min. PPM	Max. PPM	Min. PPM	Max. PPM
Boron (B)	1000	1500	600	900
Nitite (NO_2)	800	2400	300	600
Nitrates (NO_3)	1000	2000	800	1800
Silica (S_1)	100	500	100	500
Phosphorous (P)	300	500	800	1200
Molybdenum (Mo)	—	—	200	400
pH	8.5	10.5	8.5	10.5

Do not use one manufacturer's test to measure the inhibitor strength of another manufacturer's product. Always follow the manufacturer's recommended test procedures.

SILICATE DROPOUT

Excessive amounts of chemicals in the engine coolant can cause *silicate dropout*, which creates a gel–type deposit that reduces heat transfer and coolant flow.

The gel takes the color of the coolant in the wet state, but appears as a white powdery deposit when dry. Although silica gel is non–abrasive, it can pick up solid particles in the coolant and become gritty, causing excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non–acid (alkali) type heavy–duty cleaners, while the dried silicate requires engine disassembly and caustic solution or mechanical cleaning of individual components.

The total amount of chemicals in the coolant can be controlled to desirable levels by using GM 6038–M formulation antifreeze at the needed freeze protection concentration, adding inhibitors according to manufacturer's recommendations and water that meets DDC requirements.

NOTICE: *Failure to use and maintain* antifreeze/water and inhibitor coolant mixture at sufficient concentration levels can result in damage to the cooling system and its related components. Conversely, overconcentration of antifreeze and/or inhibitor can result in poor heat transfer, leading to engine overheat, silicate dropout, or both. Always maintain concentrations at recommended levels.

GENERAL COOLING SYSTEM RECOMMENDATIONS

Always maintain cooling system at the proper coolant level – Check daily. A low coolant level may cause aeration of the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing adequate heat transfer. Abnormally low coolant level can cause the water pump to become "air–bound", resulting in no coolant flow. Aerated coolant or an "air–bound" water pump can be catastrophic to engine life.

Overfilling a cooling system can result in unnecessary loss of cooolant and, in some rare cases, engine overcooling, especially during cold weather operation.

The cooling system must be pressurized to prevent localized boiling of the coolant. The system must be kept clean and leak–free. The fill cap or pressure relief valve must always be installed and checked periodically for proper operation.

Summary of Coolant Recommendations

1. Always use recommended antifreeze, inhibitor and water at proper concentration levels.
2. Use only ethylene glycol antifreeze meeting the GM 6038–M or ASTM D 3306 formulation or an equivalent antifreeze with a 0.15% maximum silicate content meeting GM 1899–M performance specifications.
3. Use an antifreeze solution year–round for freeze and boil–over protection. Seasonal changing of coolant from an antifreeze solution to an inhibitor/water solution is not recommended.
4. Pre–mix antifreeze makeup solutions at the proper concentration before adding to the cooling system.
5. Maintain the prescribed inhibitor strength levels as required. Test at each oil change interval and add inhibitor as needed. Do not use one manufacturer's test kits to measure the inhibitor strength of another manufacturer's product.
6. Follow the manufacturer's recommendations on inhibitor usage and handling. Do not mix different base inhibitor packages.
7. Use only non–chromate inhibitors.
8. Supplemental cavitation suppression inhibitors *must* be added to Series 53, 60, 92 and 149 engines after initial fill and *must* be maintained.
9. Change coolant filters at regular intervals per manufacturer's recommendation.
10. DO NOT USE THE FOLLOWING:
    - Soluble oil
    - Chromate inhibitor
    - Methoxy propanol–base antifreeze
    - Methyl alcohol–base antifreeze
    - Sealer additives or antifreezes containing sealer additives
11. Use only water meeting specifications found in Tables A–1 & A–2 (page 9). Use of distilled water is ideal.
12. Always maintain proper coolant level.
13. A cooling system properly maintained and protected with antifreeze and supplemental inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the coolant must be drained, discarded in a safe manner, and the

cooling system cleaned thoroughly. Refill cooling system with a recommended water/antifreeze /inhibitor mixture at appropriate concentration level.

CAUTION: Never remove fill cap while coolant is hot. Remove cap *slowly* and only when coolant is at ambient conditions. A sudden release of pressure from a heated cooling system can result in possible personal injury from the expulsion of hot coolant.

SECTION 14

ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations for on-highway vehicle engines; injector timing, exhaust valve clearance, engine idle and no-load speeds, throttle delay or fuel modulator settings must be checked and adjusted, if necessary, at 50,000 mile intervals (refer to Section 15.1).

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly. The following types of governors are used:

1. Limiting speed mechanical.
2. Variable speed mechanical.
3. Constant speed mechanical.
4. Hydraulic.

The mechanical governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor. A single-weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, governor or injectors have been replaced or overhauled, then certain tune-up adjustments are required. Accurate tune-up adjustments are very important if maximum performance and economy are to be obtained.

NOTICE: If a supplementary governing device, such as a load limit device, is used, it must be disconnected prior to the tune-up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune-up an engine completely, perform all of the adjustments in the applicable tune-up sequence given below.

CAUTION: To prevent the possibility of personal injury, use turbocharger inlet shield J 26554-A anytime the turbocharger inlet is exposed.

Use new valve rocker cover gaskets after the tune-up is completed.

Tune-Up Sequence For Mechanical Governor

Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the service technician must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

CAUTION: An overspeeding engine can result in engine damage which could cause personal injury.

1. Adjust the exhaust valve clearance, cold.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.
8. Adjust the throttle booster spring (variable speed governor only).
9. Adjust the supplementary governing device, if used.

Tune-up Sequence For Hydraulic Governor

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the fuel rod.
4. Position the injector rack control levers.
5. Adjust the load limit screw.
6. Compensation adjustment (PSG governors only).
7. Adjust the speed droop.
8. Adjust the maximum no-load speed.

EMISSION REGULATIONS FOR ON-HIGHWAY VEHICLE ENGINES

On-highway vehicle and coach engines built by Detroit Diesel Corporation are certified to be in compliance with Federal and California Emission Regulations established for each model year beginning with 1970.

Engine certification is dependent on five physical characteristics:

1. Fuel injector type.
2. Maximum full-load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size).

The following Charts summarize all of the pertinent data concerning the specific engine configurations required for each model year.

When serviced, all on-highway vehicle and coach engines should comply with the specifications for the specific model year in which the engine was built.

Trucks in a fleet containing engines of various model years can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

1970-1973 CERTIFIED AUTOMOTIVE CONFIGURATIONS

Year	1970	1971	1972	1973
Engines	3-53N 4-53N 6V-53N 8V-53N	3-53N 4-53N 6V-53N 8V-53N	3-53N 4-53N 6V-53N 8V-53N	3-53N 4-53N 6V-53N 8V-53N
Injectors	N40 N45 N50**	N40 N45 N50**	N40 N45 N50	C40 C45 C50
▼ Maximum Full-load Engine Speed	2800	2800	2800	2800
Camshaft Timing	Adv.	Adv.	Adv.	Adv.
■Injector Timing	1.460"	1.460"	1.460"	1.460"
Timing Gage	J 1853	J 1853	J 1853	J 1853
Throttle Delay	No	No	*Yes	*Yes
Yield Link	—	—	—	—

*Throttle delay must have .016" diameter orifice.
**Exempt for fire fighting apparatus.
▼No-load engine speed will vary with injector size and governor type.
■The adjusted height of the fuel injector follower in relation to the injector body.

1974-1976 CERTIFIED AUTOMOTIVE CONFIGURATIONS

Year	1974	1975	1976
Engines	4-53N 6V-53N	4-53N 6V-53N	4-53N 6V-53N
Injectors	C40 C45 C50	C40 C45 C50	C40 C45 C50
▼Maximum Full-load Engine Speed	2800	2800	2800
Camshaft Timing	Adv.	Adv.	Adv.
■Injector Timing	1.470"	1.470"	1.470"
Timing Gage	J 24236	J 24236	J 24236
Throttle Delay	Yes ●	Yes ●	Yes ●
Yield Link	Yes	Yes	Yes

▼No-Load engine speed will vary with injector size and governor type.
■The adjusted height of the fuel injector follower in relation to the injector body.
●.250" diameter fill hole, .016" diameter discharge orifice.

1977 CERTIFIED AUTOMOTIVE CONFIGURATIONS

Engine	4-53N	6V-53N
(a) Injectors	C40 C45 C50	C40 C45 C50
(a) Maximum Rated Speed	2800	2800
(a) Minimum Rated Speed	2800 (C40) 2400 (C45) 2500 (C50)	2600 (C40) 2500 (C45) 2100 (C50)
Gear Train Timing	Adv.	Adv.
Injector Timing	1.470"	1.470"
Timing Gage	J 24236	J 24236
Throttle Yield Link Setting	(e) Yes .454"	(e) Yes .454"
Liner Port Height Compression Ratio Blower Drive Ratio	.840" 21:1 2.487:1	.840" 21:1 2.487:1
Governor Type	Limiting Speed	
Thermostat	170-180° F (77-82° C) Nominal Opening Temperature	

(a) Not to exceed injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type.

(e) Large fill hole (.250" dia.), .016" discharge orifice. Use a minimum idle speed at 500 rpm on all engines.

1978 CERTIFIED AUTOMOTIVE CONFIGURATIONS

	FEDERAL			CALIFORNIA
ENGINE FAMILIES	4L-53N	4-53T	6V-53N	4-53TC
INJECTORS (a)	C40 C45 C50	5A55 5A60	C40 C45 C50	5A55 5A60
MAXIMUM FULL LOAD SPEED (b)	2800	2500	2800	2500
MINIMUM FULL LOAD SPEED	2400	2500	2400	2500
CAMSHAFT LOBE POSITION	ADV.	STD.	ADV.	STD.
INJECTOR TIMING	1.470	1.496	1.470	5A55-1.496 5A60-1.508
THROTTLE DELAY YIELD LINK	(e) REQ.	FUEL MODULATOR	(e) REQ.	FUEL MODULATOR
TURBOCHARGER A/R		T04B98 .96 3LM-353 2.7 Sq. In.		T04B98 .96 3LM-353 2.7 Sq. In.

(a) See Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.
(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.
(e) Large fill hole (.250" dia.), .016" discharge orifice.

FUEL INJECTOR TIMING GAGE CHART

INJECTOR	TOOL NO.	SETTING	CAM LOBE POSITION
5A55	J 9595	1.496	Standard
5A60	J 9595	1.496	Standard
5A60 (Calif. Cert. only)	J 8909	1.508	Standard

1979 CERTIFIED AUTOMOTIVE CONFIGURATIONS

	FEDERAL		CALIFORNIA	
FAMILIES	4L-53T	6V-63T	4L-53TC	6V-53TC
INJECTORS	5A55 5A60	5A50	5A55 5A60	5A50
MAXIMUM FULL LOAD SPEED	2500	2600	2500	2600
MINIMUM FULL LOAD SPEED	2500	2500	2500	2500
MINIMUM IDLE SPEED	500	500	500	500
GEAR TRAIN TIMING	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.496	1.490	5A55-1.496 5A60-1.508	1.500
FUEL MODULATOR SETTING #	.365#	.404#	5A55-.365 5A60-.404#	.404#
LINER PORT HEIGHT	.84	.84	.84	.84
LINER PART NUMBER	5132803	5132803	5132803	5132803
TURBOCHARGER A/R	TO4B98 .96 A/R ##	TV6123 1.20 A/R	TO4B98 .96 A/R ##	TV6123 1.20 A/R
TURBOCHARGER PART NUMBER	5103905##	5104082	5103905##	5104082
BLOWER DRIVE RATIO	2.49:1	2.49:1	2.49:1	2.49:1
BLOWER PART NUMBER	5103563-LH 5103466-RH	5104298	5103563-L 5103466-R	5104298
COMPRESSION RATIO	18.7:1	18.7:1	18.7:1	18.7:1
EXHAUST VALVE MATERIAL	NIMONIC 90	NIMONIC 90	NIMONIC 90	NIMONIC 90
EXHAUST VALVE PART NUMBER	5109925	5109925	5109925	5109925
CERTIFICATION LABEL NUMBER	14B7-264	14B7-266	14B7-265	14B7-267

53T Uses fuel modulator.
Optional 3LM-353, 2.7 Sq. in., 5104803.

THROTTLE DELAY AND STARTING AID GAGES

J 28779 For .365"
J 28479 For .395"
J 9509-2 For .404"
J 23190 For .454"
J 25559 For .570"
J 26646 For .290"

PIN GAGE

J 25558 For .069" & .072"

TIMING GAGES

J 1853 For 1.460"
J 24236 For 1.470"
J 1242 For 1.484"
J 29066 For 1.490"
J 9595 For 1.496"
J 25454 For 1.500"
J 8909 For 1.508"

FEDERAL

ENGINE FAMILIES	4L-53T	6V-53T
INJECTORS (a)	5A55 5A60	5A50
MAXIMUM FULL LOAD SPEED (a)	2500	2600
MINIMUM FULL LOAD SPEED	2500	2500 (b) 2200 (c)
MINIMUM IDLE SPEED	500	600
GEAR TRAIN TIMING	STD.	STD.
INJECTOR TIMING	1.496	1.490
THROTTLE DELAY SETTING	.365 (e)	.404 (e)
TURBOCHARGER A/R	T04B98 .96 A/R 3LM-353 2.7 Sq. In.	TV6123 21.20 A/R

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.
(b) 1980
(c) 1981
(e) 53T uses fuel modulator.

1980 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800

1981 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	215 @ 2200 223 @ 2500 225 @ 2600	550 @ 1800

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG. (98.19 kPa) — BAROMETER (DRY)

1982 CERTIFIED AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	4L-53T	6V-53T
INJECTORS (a)	5A55 5A60	5A50
MAX. FULL LOAD SPEED	2500	2600
MIN. FULL LOAD SPEED	2500	2200
MIN. IDLE SPEED	500	600
GEAR TR. TIMING	STD.	STD.
INJECTOR TIMING	1.496	1.490
THROTTLE DELAY SETTING	.365 (a)	.404 (a)
LINER PORT HGHT.	.84	.84
LINER PART NO.	5132803	5132803
TURBOCHARGER A/R	T04B98 (b) .96 A/R (c)	TV6123 1.20 A/R
TURBOCHARGER P/N	5103905	5104082
BLOWER DR. RATIO	2.49:1	2.49:1
BLOWER PART NO.	5107528L 5107527R	5107523
COMP. RATIO	18.7:1	18.7:1
EXHAUST VALVE P/N	5109925	5109925
CERT. LABEL NO.	14B7-327	14B7-328

(a) 53T uses fuel modulator.
(b) For "RD" configuration optional turbocharger 5106635 & 5106636 are available.
(c) Optional 3LM-353, 2.7 sq. in. 5104803.

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS 85°F (29.4°C) — AIR INLET TEMPERATURE 29.00 IN. HG. (98.19 kPa) — BAROMETER (DRY)			

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

1983 CERTIFIED AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	4L-53T	6V-53T
INJECTORS (a)	5A55 5A60	5A50
MAXIMUM FULL LOAD SPEED (a)	2500	2600
MINIMUM FULL LOAD SPEED	2500	2200
MINIMUM IDLE SPEED	500	600
GEAR TRAIN TIMING	STD.	STD.
INJECTOR TIMING	1.496	1.490
MODULATOR SETTING	.365	.404
TURBOCHARGER A/R	T04B98 .96 A/R 3LM-353 2.7 Sq. In.	TV6123 1.20 A/R
TURBOCHARGER PART NO.	5103905 5104803	5104082
BLOWER DRIVE RATIO	2.49:1	2.49:1
BLOWER PART NO.	5107528L 5107527R	5107523
COMPRESSION RATIO	18.7:1	18.7:1
EXHAUST VALVE PART NO.	5109925	5109925
LINER PART NO.	5132803	5132803
LINER PORT HEIGHT	.84	.84
CERT. LABEL NO.	14B7-347	14B7-348

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS 85°F (29.4°C) — AIR INLET TEMPERATURE 29.00 IN. HG. (98.19 kPa) — BAROMETER (DRY)			

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

1984 CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4L-53T	6V-53T
Injectors (a)	5A55 5A60	5A50
Maximum Full Load Speed (a)	2500	2600
Minimum Full Load Speed	2500	2200
Minimum Idle Speed	500	600
Gear Train Timing	Std.	Std.
Injector Timing	1.496	1.490
Throttle Delay Setting	DNA	DNA
Modulator Setting	.365	.404
Turbocharger A/R	T04B98 .96 A/R 3LM-353 2.7 Sq. In.	TV6123 1.20 A/R
CERT. LABEL NO.	14B7-373	14B7-374

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 18SA315) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

1984 CERTIFIED AUTOMOTIVE ENGINES			
ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE J 1349 CONDITIONS			

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm–up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

ENGINES WITH TWO–VALVE CYLINDER HEADS

Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker cover(s) and remove the cover(s). Discard the gasket(s).

2. Place the governor speed control lever in the *idle speed* position. If a stop lever is provided, secure it in the *stop* position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

4. Loosen the exhaust valve rocker arm push rod locknut.

5. Place an .011" feeler gage (J 9708–01) between the exhaust valve stem and the rocker arm (Fig. 1). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .010" feeler gage (J 9708–01 will pass freely between the valve stem and the rocker arm, but the .012" feeler gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

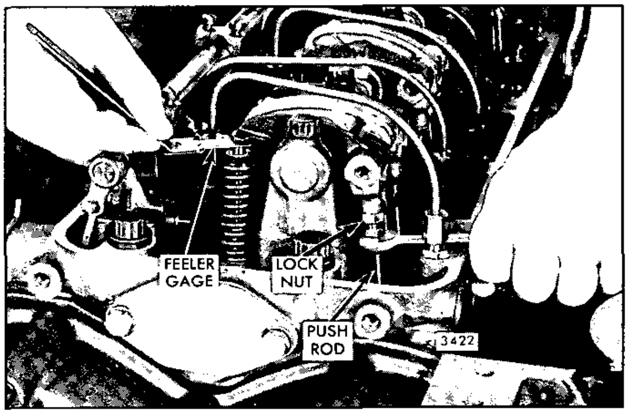


Fig. 1 – Adjusting Valve Clearance (Two Valve Head)

Valve Clearance Adjustment (Hot Engine)

It is *not* necessary to make a final hot engine exhaust valve clearance adjustment after a cold engine adjustment has been performed. However, if a hot engine adjustment is desired, use the following procedure.

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve

clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full load, may become insufficient.

NOTICE: Since these adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

1. With the engine at normal operating temperature (refer to Section 13.2), set the exhaust valve clearance with feeler gage J 9708–01. At this time, if the valve clearance is correct, the .008" gage will pass freely between the end of the valve stem and the rocker arm and the .010" gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine at 100°F (38°C) or less, check the valve clearance.

2. If a .011" feeler gage (ç.004") will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary, adjust the push rod.

ENGINES WITH FOUR–VALVE CYLINDER HEADS

Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker cover(s) and remove the cover(s). Discard the gasket(s).

2. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

4. Loosen the exhaust valve rocker arm push rod locknut.

5. Place a .026" feeler gage (J 9708–01) between the end of one exhaust valve stem and the rocker arm bridge (Fig. 2). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .025" feeler gage will pass freely between the end of one valve stem and the rocker arm bridge, but the .027" feeler gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

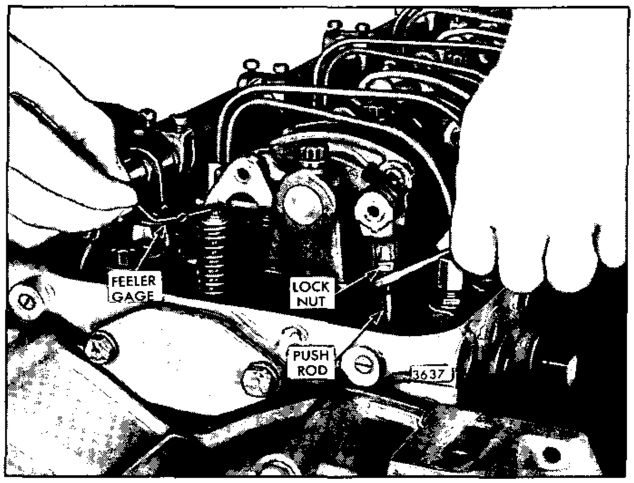


Fig. 2 – Adjusting Valve Clearance (Four Valve Head)

 May, 1990

Valve Clearance Adjustment (Hot Engine)

It is *not* necessary to make a final hot engine exhaust valve clearance adjustment after a cold engine adjustment has been performed. However, if a hot engine adjustment is desired, use the following procedure.

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full load, may become insufficient.

NOTICE: Since these adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

1. With the engine at normal operating temperature (refer to Section 13.2), set and exhaust valve clearance with feeler gage J 9708–01. At this time, if the valve clearance is correct, the .023″ gage will pass freely between the end of one valve stem and the rocker arm bridge, but the .025″ feeler gage will not pass through. Readjust the push rod, if necessary.
2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine at 100°F (38°C) or less, check the valve clearance.
2. If a .026″ feeler gage (ç.006″) will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary, adjust the push rod.

FUEL INJECTOR TIMING

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft.

Refer to the *General Specifications* at the front of the manual for the engine firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted (Section 14.1), time the fuel injectors as follows:

1. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

- **NOTICE:** The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should always be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

- **NOTICE:** Barring a left–hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

- **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

3. Place the small end of the injector timing gage in the hole provided in the top of the injector body with the flat of the gage toward the injector follower (Fig. 1). Refer to the engine option label for the correct timing dimension. Refer to Table 1 or 2 for the correct timing gage (for vehicle engines, refer to Section 14).

4. Loosen the injector rocker arm push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and, if necessary, readjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune–up is required, install the valve rocker cover, using a new gasket.

TRUNK PISTONS

Injector	Timing Dimension	Timing Gage	Camshaft Timing	Engine
35	1.484"	J 1242	Standard	53 (2 valve)
35	1.508"	J 8909	Standard	(Reefer Car)
40	1.484"	J 1242	Standard	53, V53
45	1.484"	J 1242	Standard	53, V53
S40	1.460"	J 1853	Standard	53, V53
S45	1.460"	J 1853	Standard	53, V53
S50	1.460"	J 1853	Standard	53, (2 valve)
L40	1.460"	J 1853	Standard	(Lift Truck)
N35	1.460"	J 1853	—	—
N35	1.484"	J 1242	Standard	—
N35	1.508"	J 8909	Standard	Reefer Car
N40	1.460"	J 1853	Standard	53N, V53N
N40	1.460"	J 1853	Standard	—
N45	1.460"	J 1853	Standard	53N, V53N
N45	1.460"	J 1853	Standard	—
N45	1.484"	J 1242	Standard	—
N50	1.460"	J 1853	Standard	53N, V53N
N50	1.460"	J 1853	Standard	—
N60	1.460"	J 1853	—	—
N60	1.460"	J 1853	Standard	SGS*
N65	1.508"	J 8909	Standard	4–53T
N65	1.508"	J 8909	Standard	Industrial & SGS*
N65	1.460"	J 1853	Standard	SGS*
N65	1.508"	J 8909	Standard	Generator
N70	1.460"	J 1853	Standard	Marine
N70	1.460"	J 1853	—	—
N70	1.460"	J 1853	Standard	SGS*
M40	1.460"	J 1853	Standard	SGS*
M55	1.460"	J 1853	Standard	SGS*
M60	1.460"	J 1853	Standard	SGS*
5N65	1.460"	J 1853	Standard	6V–53T
5N65	1.460"	J 1853	Standard	Marine
5N45	1.460"	J 1853	Standard	—
5A50	1.490"	J 29066	Standard	Industrial
5A50	1.484"	J 1242	Standard	6V–53T†
5A55	1.496"	J 9595	Standard	Industrial
5A55	1.484"	J 1242	Standard	3–53T†
5A55	1.484"	J 1242	Standard	6V–53T†
5A60	1.496"	J 9595	Standard	Industrial & SGS*
5A60	1.484"	J 1242	Standard	SGS*
5A60	1.484"	J 1242	Standard	3–53T†

For automotive applications, refer to Section 14.
* Special Gov't. Sale
† With bypass blower.

TABLE 1 – INJECTOR TIMING

CROSS-HEAD PISTONS

Injector	Timing Dimension	Timing Gage	Camshaft Timing	Engine
5C50	1.480"	J 29065	Standard	4-53T 6V-53T
5E50	1.480"	J 29065	Standard	3-53T
5C55	1.480"	J 29065	Standard	4-53T 6V-53T
5E55	1.480"	J 29065	Standard	3-53T
5C60	1.480"	J 29065	Standard	4-53T 6V-53T
5E60	1.480"	J 29065	Standard	3-53T

TABLE 2 – INJECTOR TIMING

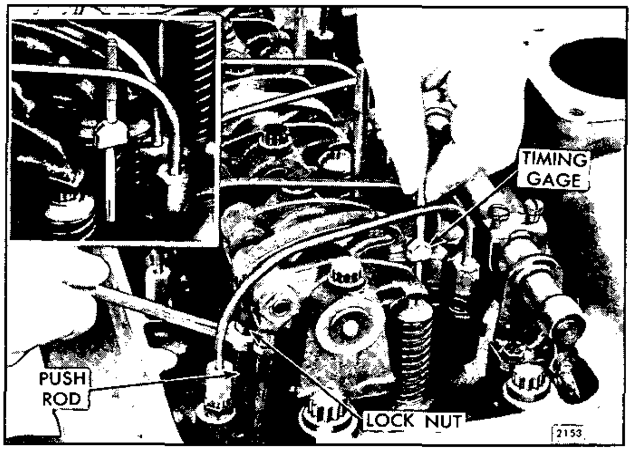


Fig. 1 – Timing Fuel Injector

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINE

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTICE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device, as outlined in Section 14.14.

A 3/4"–16 tapped hole has been added to the SAE No. 2 flywheel housings used on certain 4–53 turbocharged engines. The tapped hole located at the 7:30 o'clock position on the bottom rail accomodates the probe for the digital tachometer J 26791. A 3/4"–16 plug is used to seal this tachometer pick–up hole.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high–speed spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut.
3. Start the engine and adjust the idle speed screw to obtain an idle speed of 500–600 rpm (Fig. 8). The recommended idle speed is 500–600 rpm, but may vary with special engine applications.
4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gasket.
5. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever. *Do not overspeed the engine.*
6. Check the gap between the low–speed spring cap and the high–speed spring plunger with a feeler gage (Fig. 1). The gap should be .002"–.004". If the gap setting is incorrect, reset the gap adjusting screw.
7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

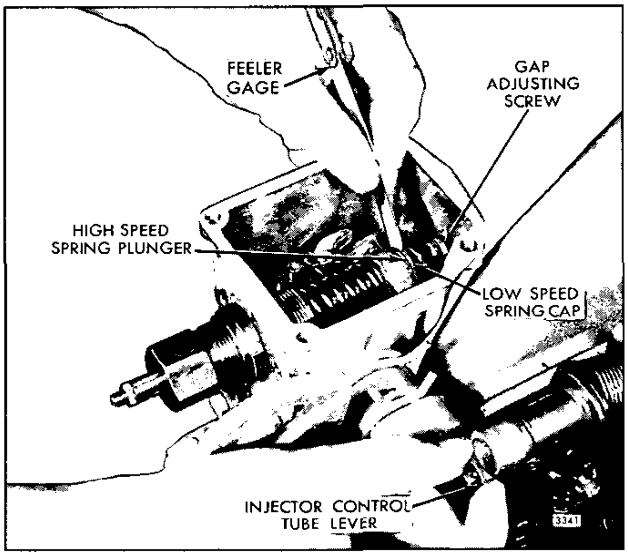


Fig. 1 – Adjusting Governor Gap

8. Recheck the gap with the engine operating between 1100 and 1300 rpm and readjust, if necessary.
9. Install the governor cover. The governor cover should be placed on the housing with the pin of the speed control lever projecting into the slot in the differential lever.
10. Install the screws and lock washers finger tight. Pull the cover away from the engine and tighten the screws. This step will properly locate the cover on the governor housing.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Governor low–speed gap closed.
3. High–speed spring plunger on the seat in the governor control housing.
4. Injector racks in the *full–fuel* position.

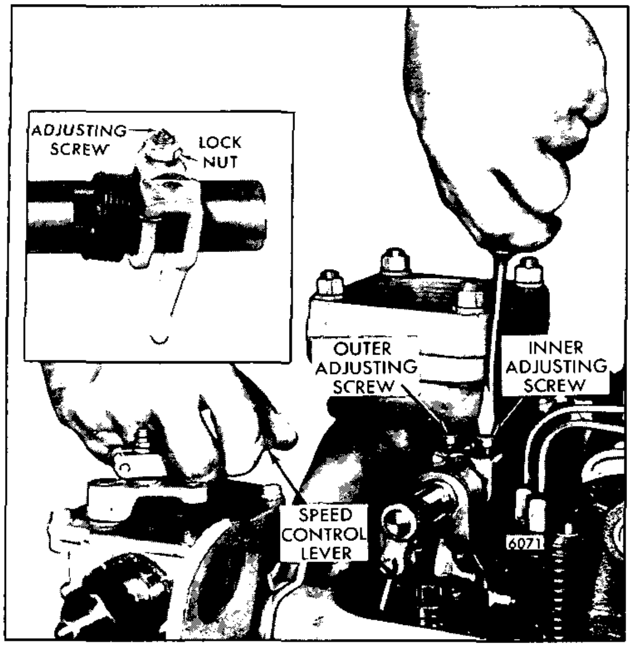


Fig. 2 – Positioning the Rear Injector Rack Control Lever

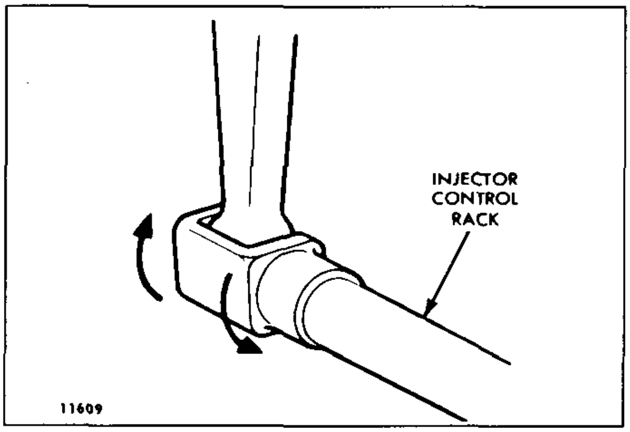


Fig. 3 – Checking Rotating Movement of Injector Control Rack

Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12–14 threads) project from the locknut, when the nut is against the high–speed plunger. This adjustment lowers the tension of the low–speed spring so it can be easily compressed. This permits closing the low–speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch.*

NOTICE: A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

3. Back out the buffer screw approximately 5/8", if it has not already been done.

4. Loosen all of the inner and outer injector rack control lever adjusting screws or the adjusting screws and locknuts (Fig. 2). Be sure all of the levers are free on the injector control tube.

5. Move the speed control lever to the full fuel position and hold it in that position with light finger pressure.

Two Screw Assembly

Turn the inner adjusting screw on the rear injector rack control lever down until a slight movement of the control lever is observed or a step–up in effort to turn the screwdriver is noted. This will place the rear injector rack in the *full–fuel* position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly

Tighten the adjusting screw of the rear injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the rear injector rack in the full–full position.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adusting screws is 24–36 **lb–in** (3–4 N·m).

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

6. To be sure of the proper rack adjustment, hold the speed control lever in the *full–fuel* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the speed control lever is in the maximum speed position (Fig. 3). Hold the speed control lever in the maximum speed position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward and when the pressure of the screwdriver is released, the control rack should "spring" back upward (Fig. 4).

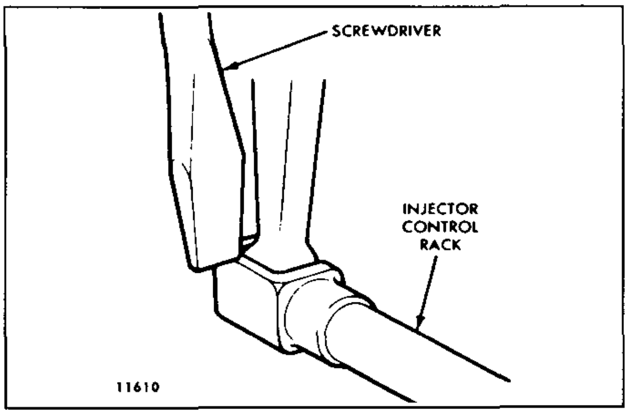


Fig. 4 – Checking Injector Rack "Spring"

If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly,* back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly* loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

The setting is too tight if, when moving the speed control lever from the no speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step–up in effort required to move the speed control lever to the end of its travel. To correct this condition with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

7. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever. Hold the injector control racks in the *full–fuel* position by means of the lever on the end of the control tube and proceed as follows:

   Two Screw Assembly

   a. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the *full–fuel* position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

   b. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

   c. Position the remaining injector rack control levers as outlined in Steps 6 and 7.

   NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

   One Screw and Locknut Assembly

   a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

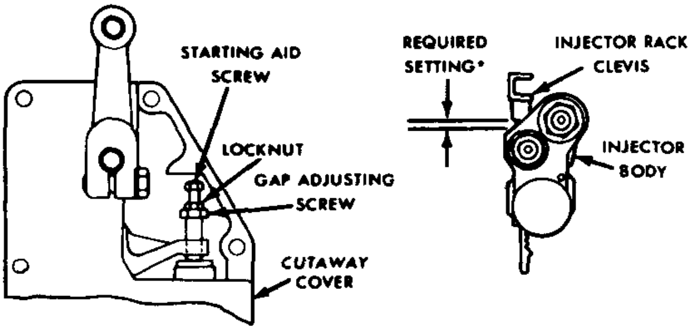
   NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

   b. Verify the rear injector rack adjustment, as outlined in Step 7. If it does not "spring" back upward, turn the adjacent injector rack adjusting screw counterclockwise slightly until the rear injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both the rear and the adjacent injectors. Turn clockwise or counterclockwise the adjacent injector rack adjusting screw until both the rear and the adjacent injector racks are in the *full–fuel* position when the locknut is securely tightened.

   c. Adjust the remaining injectors using the proceedures outlined in Step "b", always verifying proper injector rack adjustment.

8. Connect the fuel rod to the injector control tube lever.

9. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting the engine. Tighten the locknut.



INJECTOR	GAGE SETTING*	TOOL NUMBER
5A55	.345"	J 24889
5A60	.345"	J 24889
N55	.345"	J 24889
N60	.345"	J 24889
N65	.385"	J 24882
N70	.385"	J 24882
M60	.345"	J 24889
M70	.385"	J 24882

L-5870

Fig. 5 – Starting Aid Screw Adjustment

10. On *turbocharged engines* adjust the internal starting aid screw, as follows:

    The starting aid screw has a locknut and the gap adjusting screw has a self locking patch.

    a. Install a cutaway governor cover assembly, on the governor housing (Fig. 5).

    b. With the engine *stopped,* place the governor stop lever in the *run* position and the speed control lever in the *idle* position.

    c. Hold the gap adjusting screw to keep it from turning and adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the counterbore in the injector body (Fig. 5). Move the gage back and forth along the injector rack until a clearance of 1/64" is noted. The setting is measured at any convenient cylinder. Tighten the locknut on the starting aid screw sufficiently to prevent oil leakage as well as to hold the adjusting screw setting.

    d. Check the injector rack clevis–to–body clearance after performing the following:

        1. Position the stop lever in the *run* position.

        2. Move the speed control lever from the *idle* position to the maximum speed position.

        3. Return the speed control lever to the *idle* position.

    Movement of the governor speed control lever is to take up clearances in the governor linkage. The clevis–to–body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjustment screw.

    e. Start the engine and recheck the running gap (.0015") and, if necessary, reset it and reposition the injector racks. Then stop the engine.

    f. Remove the cutaway governor cover assembly.

    g. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes of the cover. Tighten the screws.

CAUTION: Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the no–fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

11. Use a new gasket and reinstall the valve rocker cover.

Adjust Maximum No–Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine option plate, set the maximum no–load speed as follows:

TYPE A GOVERNOR SPRINGS (Fig. 7):

1. Loosen the locknut (Fig. 6) and back off the high–speed spring retainer approximately five turns.

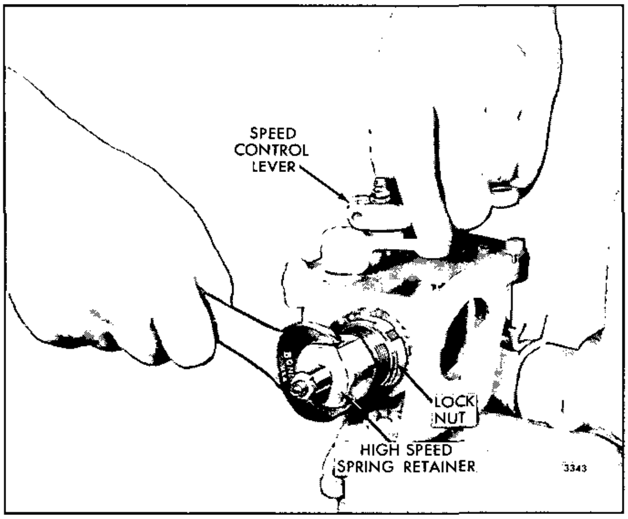


Fig. 6 – Adjusting Maximum No–Load Speed

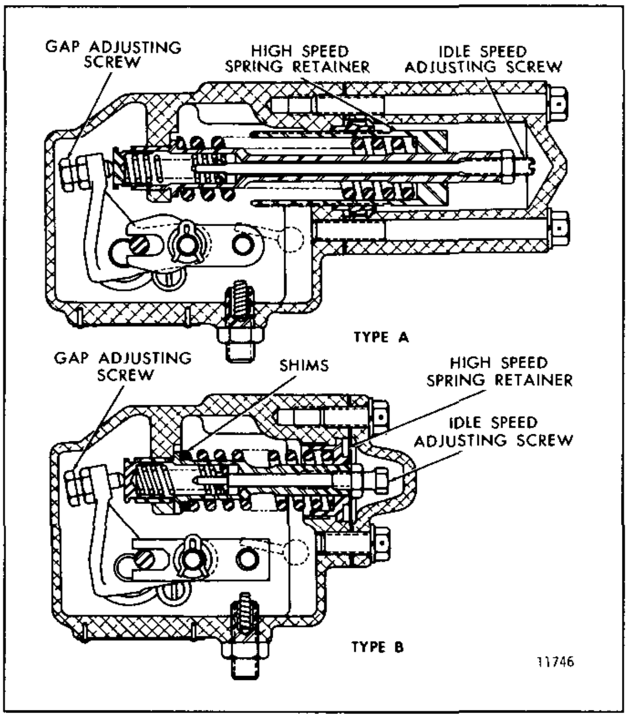


Fig. 7 – Governor Spring Assemblies

2. With the engine at operating temperature and no load on the engine, place the speed control lever in the *full–fuel* position. Turn the high–speed spring retainer IN until the engine is operating at the recommended no–load speed.

   The best method of determining the engine speed is with an accurate tachometer.

3. Hold the high–speed spring retainer and tighten the locknut.

TYPE B GOVERNOR SPRINGS (Fig. 7):

1. Start the engine and after it reaches normal operating temperature, remove the load from the engine.
2. Place the speed control lever in the maximum speed position and note the engine speed.
3. Stop the engine and, if necessary, adjust the no–load speed as follows:

   a. Remove the high–speed spring retainer, high–speed spring and plunger.

      NOTICE: To prevent the low–speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

   b. Remove the high–speed spring from the high–speed plunger and add or remove shims as required to establish the desired engine no–load speed. *For each .010" shim added, the engine speed will be increased approximately 10 rpm.*

   c. Install the high–speed spring on the high–speed spring plunger and assemble the spring assembly in the governor housing. Install the spring retainer in the governor housing and tighten it securely.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* posiiton. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

   d. Start the engine and recheck the engine no–load speed. Repeat the steps above as necessary to establish the no–load speed.

Adjust Idle Speed

With the maximum no–load speed properly set, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed (Fig. 8).

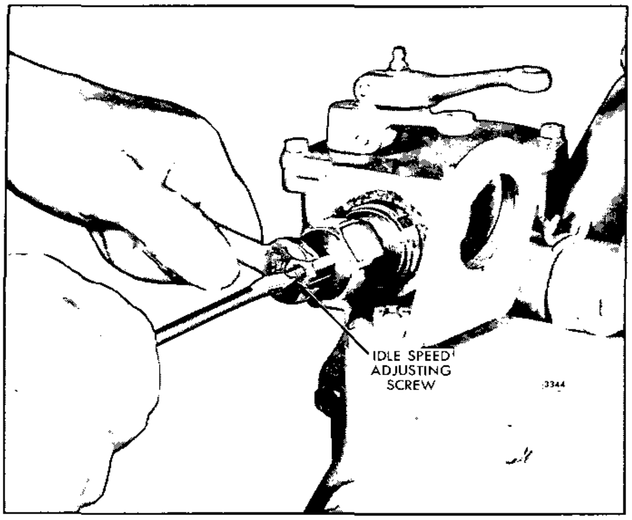


Fig. 8 – Adjusting Engine Idle Speed

The recommended idle speed is 500–600 rpm, but may vary with the particular engine application.

2. Hold the idle speed adjusting screw and tighten the locknut.

3. Install the high–speed spring cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, loosen the locknut and turn the buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 9). *Do not increase the engine idle speed more than 15 rpm with the buffer screw.*

2. Recheck the maximum no–load speed. If it has increased more than 25 rpm from the maximum speed attained in Step 1, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the locknut.

If the engine is equipped with a supplementary governing device, refer to Section 14.14 and adjust it at this time.

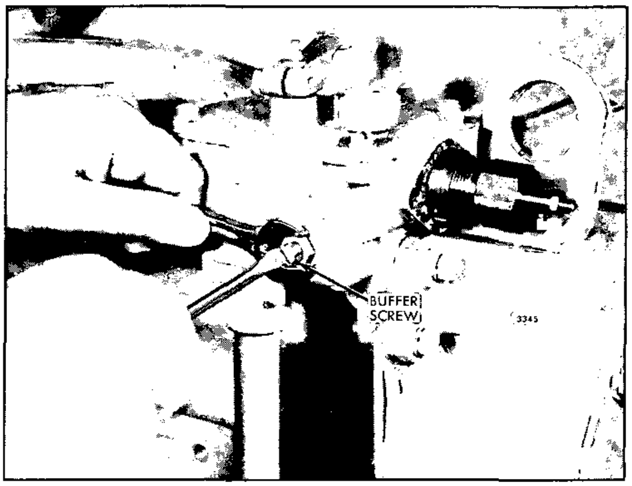


Fig. 9 – Adjusting the Buffer Screw

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (V-TYPE ENGINE)

6V-53 ENGINE

The limiting speed mechanical governor is mounted at the rear of the engine, between the flywheel housing and the blower (Fig. 1). The governor is driven by the right blower rotor drive gear. The left blower rotor drive gear is driven by a shaft that passes through the governor housing from the engine gear train. There are two types of limiting speed governor assemblies. The difference in the two governors is in the spring mechanism (Fig. 8). One has a long spring mechanism, the other has a short spring mechanism.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high-speed spring retainer cover.
2. Back out the buffer screw (Fig. 10) or de-energize the fast idle cylinder until it extends approximately 5/8" from the locknut.

   NOTICE: Do not back the buffer screw out beyond the limits given, or the control link lever may disengage the differential lever.

3. Start the engine and loosen the idle speed adjusting screw locknut. Then adjust the idle screw to obtain the desired idle speed (Fig. 9). Hold the screw and tighten the locknut to hold the adjustment. Governors used in turbocharged engine include a starting aid screw and locknut threaded into the governor gap adjusting screw.
4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.
5. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever. *Do not overspeed the engine.*
6. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 2). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

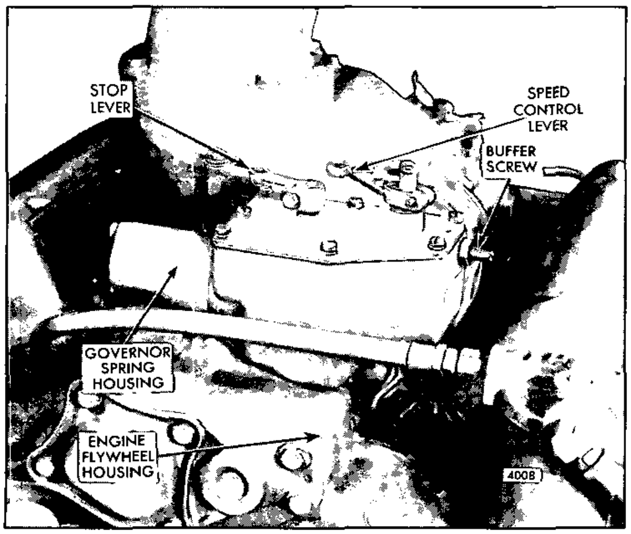


Fig. 1 – Limiting Speed Governor Mounting

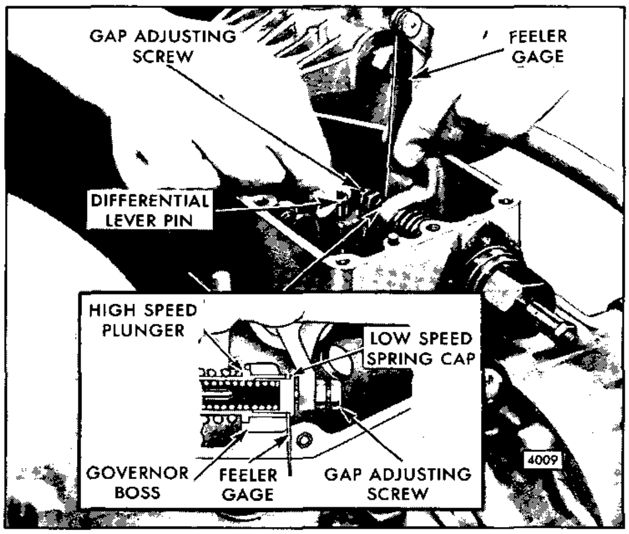


Fig. 2 – Adjusting Governor Gap

7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

8. *Recheck the gap with the engine operating* between 1100 and 1300 rpm and readjust, if necessary.

9. Stop the engine and, using a new gasket reinstall the governor cover. Do not install the governor cover and lever assembly at this time on turbocharged engines as they include an internal starting aid screw and locknut.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.

2. *Governor low–speed gap closed.*

3. High–speed spring plunger on the seat in the governor control housing.

4. Injector fuel control racks in the *full–fuel* position.

Fig. 3 – Positioning No. 3L Injector Rack Control Lever

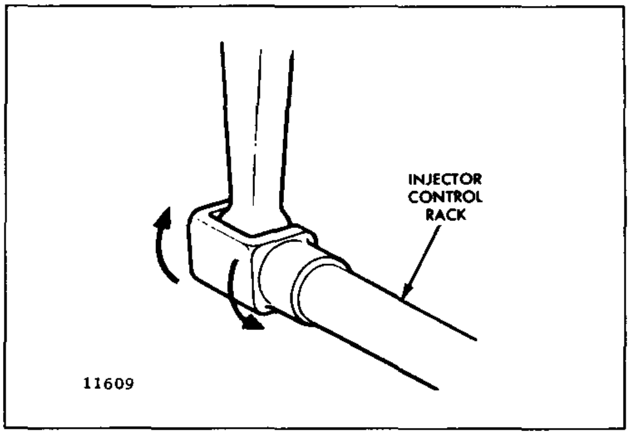


Fig. 4 – Checking Rotating Movement of Injector Control Rack

The letters "R" or "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 3L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect the linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12–14 threads) project from the locknut when the nut is against the high–speed plunger. This adjustment lowers the tension of the low–speed spring *so it can be easily compressed.* This permits closing the low–speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch.*

NOTICE: A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

3. Back out the buffer screw approximately 5/8" if it has not already been done.

4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws or the adjusting screws and locknuts on both injector control tubes (Fig. 3). Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the *maximum speed position and hold it in that position with light finger* pressure.

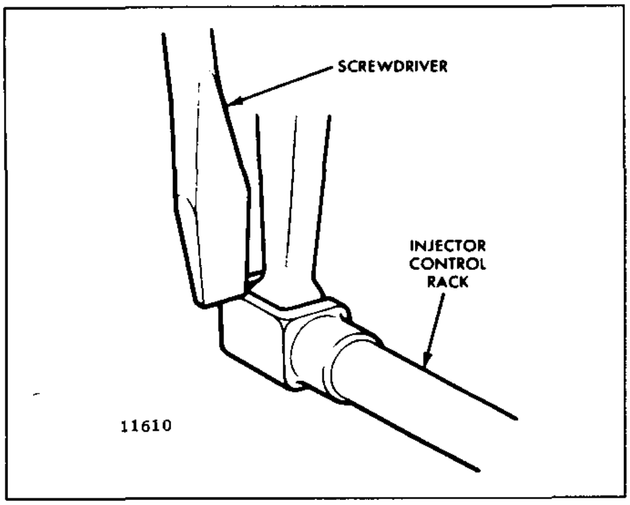


Fig. 5 - Checking Injector Control Rack Spring

Two Screw Assembly

Turn the inner adjusting screw on the No. 3L injector rack control lever down until a slight movement of the control tube lever is observed or a step–up in effort to turn the screwdriver is noted (Fig. 3). This will place the No. 3L injector in the *full–fuel* position.

Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly

Tighten the adjusting screw of the No. 3L injector rack control lever until the injector rack clevis is observed to roll up up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 3L injector rack in the *full–fuel* position.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

7. To be sure of the proper rack adjustment, hold the speed control lever in the *maximum speed* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the speed control lever is in the *maximum speed* position (Fig. 4). Hold the speed control lever in the *maximum speed* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward and when the pressure of the screwdriver is released, the control rack should "spring" back upward (Fig. 5).

   If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly,* back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

   The setting is too tight if, when moving the speed control lever from the *no–speed* position to the *maximum speed* position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step–up in effort required to move the speed control lever to the end of its travel. To correct this condition with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

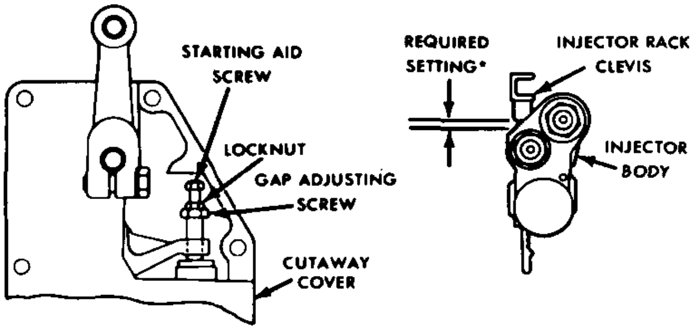
9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 3R injector rack control lever as previously outlined in Step 6 for the No. 3L injector rack control lever.

10. Insert the clevis pin in the fuel rod and the left cylinder bank injector control tube lever. Repeat the check on the No. 3L and 3R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

11. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rods and the injector control tube levers. Hold the injector control racks in the *full–fuel* position by means of the lever on the end of the control tube and proceed as follows:

    Two Screw Assembly

    a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the *full–fuel* position).



INJECTOR	GAGE SETTING*	TOOL NUMBER
5A55	.345″	J 24889
5A60	.345″	J 24889
N55	.345″	J 24889
N60	.345″	J 24889
N65	.385″	J 24882
N70	.385″	J 24882
M60	.345″	J 24889
M70	.385″	J 24882

L-5870

Fig. 6 – Starting Aid Screw Adjustment

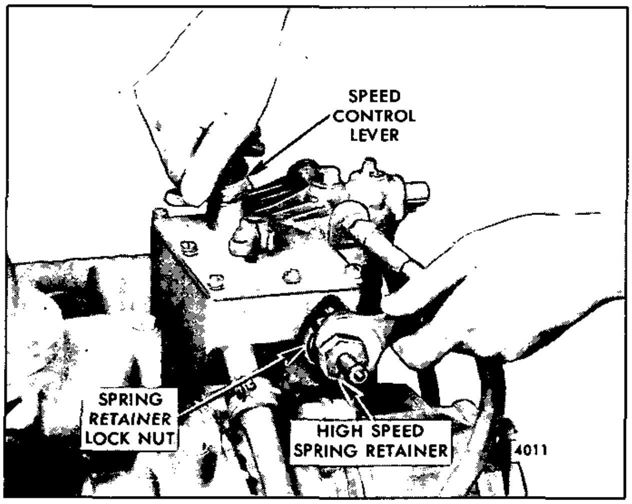


Fig. 7 – Adjusting Maximum No–Load Engine Speed

b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

c. While still holding the control tube lever in the full fuel position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 7. Tighten the screws.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

One Screw and Locknut Assembly

a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

b. Verify the injector rack adjustment of No. 3L as outlined in Step 7. If No. 3L does not "spring" back upward, turn the No. 2L adjusting screw counterclockwise slightly until the No. 3L injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 3L and No. 2L injectors. Turn clockwise or counterclockwise the No. 2L injector rack adjusting screw until both No. 3L and No. 2L injector racks are in the *full–fuel* position when the locknut is securely tightened.

c. Adjust the remaining injectors using the proceedures outlined in Step "b" always verifying proper injector rack adjustment.

Once the No. 3L and No. 3R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

12. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the *full–fuel* position, check each control rack as in Step 7. All of the control racks must have the same "spring" condition with the control tube lever in the *full–fuel* position.

13. Insert the clevis pin in the fuel rod and the injector control tube levers.

14. Turn the idle speed adjusting screw in until it projects 3/16″ from the locknut to permit starting of the engine.

15. On *turbocharged engines* adjust the internal starting aid screw, as follows:

    The starting aid screw has a locknut and the gap adjusting screw has a self locking patch.

    a. Install a cutaway governor cover assembly, on the governor housing (Fig. 6).

    b. With the engine stopped, place the governor stop lever in the *run* position and the speed control lever in the *idle* position.

    c. Hold the gap adjusting screw to keep it from turning and adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the counter bore in the injector body (Fig. 6). Move the gage back and forth along the injector rack until a clearance of 1/64" is noted. The setting is measured at the No. 3R injector rack clevis. Tighten the locknut on the starting aid screw sufficiently to prevent oil leakage as well as to hold the adjusting screw setting.

    d. Check the injector rack clevis–to–body clearance after performing the following.

        1. Position the stop lever in the *run* position.

        2. Move the speed control lever from the *idle* position to the *maximum speed* position.

        3. Return the speed control lever to the *idle* position.

        Movement of the governor speed control lever is to take up clearances in the governor linkage. The clevis–to–body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjustment screw.

    e. Start the engine and recheck the running gap (.0015") and, if necessary, reset it and reposition the injector racks. Then stop the engine.

    f. Remove the cutaway governor cover assembly.

    g. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and thae dowel pins in the housing in the dowel pin holes of the cover. Tighten the screws.

CAUTION: Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

16. Use new gaskets and reinstall the valve rocker covers.

Adjust Maximum No–Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine name plate, set the maximum no–load speed as follows:

TYPE A GOVERNOR SPRINGS (Fig. 8):

1. Loosen the locknut with a spanner wrench and back off the high–speed spring retainer several turns. Then start the engine and increase the speed slowly. If the speed exceeds the required no–load speed before the speed control lever reaches the end of its travel, back off the spring retainer a few additional turns.

2. With the engine at operating temperature and no load on the engine, place the speed control lever in the *maximum speed* position. Turn the high–speed spring retainer in (Fig. 7) until the engine is operating at the recommended no–load speed. Use an accurate hand tachometer to determine the engine speed. The maximum no–load speed varies with the full–load operating speed.

3. Hold the high speed spring retainer and tighten the locknut.

TYPE B GOVERNOR SPRINGS (Fig. 8):

1. Start the engine and, after it reaches normal operating temperature, remove the load from the engine.

2. Place the speed control lever in the *maximum speed* position and note the engine speed.

3. Stop the engine and, if necessary, adjust the no–load speed as follows:

    a. Remove the high–speed spring retainer with tool J 5895 and withdraw the high–speed spring and plunger assembly.

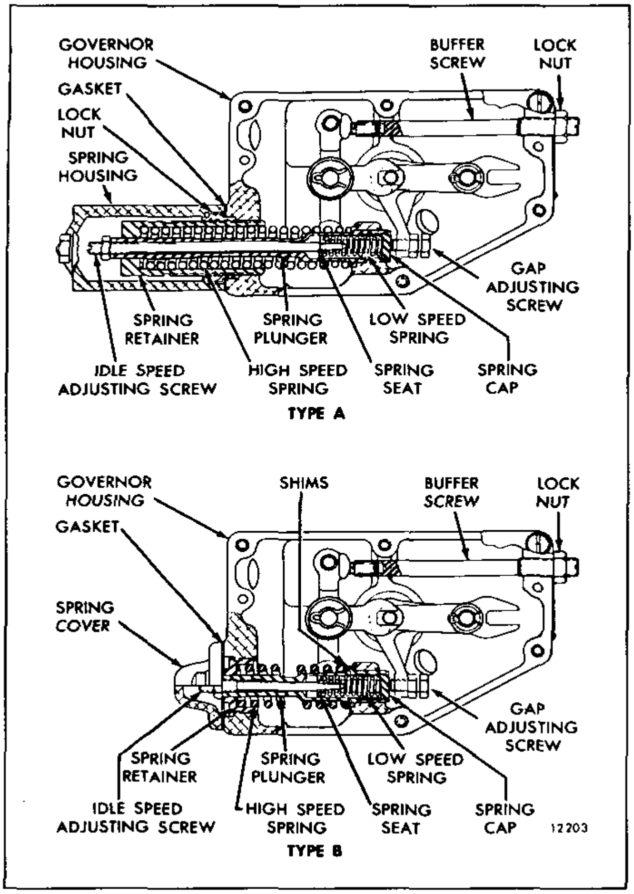


Fig. 8 – Governor Spring Assemblies

NOTICE: To prevent the low–speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

b. Remove the high–speed spring from the high–speed spring plunger and add or remove shims as required to establish the desired engine no–load speed. For each .010" in shims added, the engine speed will be increased approximately 10 rpm.

c. Install the high–speed spring on the plunger and install the spring assembly in the governor housing. Tighten the spring retainer securely. The maximum no–load speed varies with the full–load operating speed desired (Table 1).

If the full–load speed is to be 2800 rpm, then the no–load speed setting should be 2940 rpm (2800rpm + 140 rpm) to ensure the governor will move the injector racks into the *full–fuel* position at the desired full–load speed.

Full Load RPM	Maximum Governor Droop RPM
2401-2600	150
2601-2800	140

TABLE 1 – Engine Speed Droop

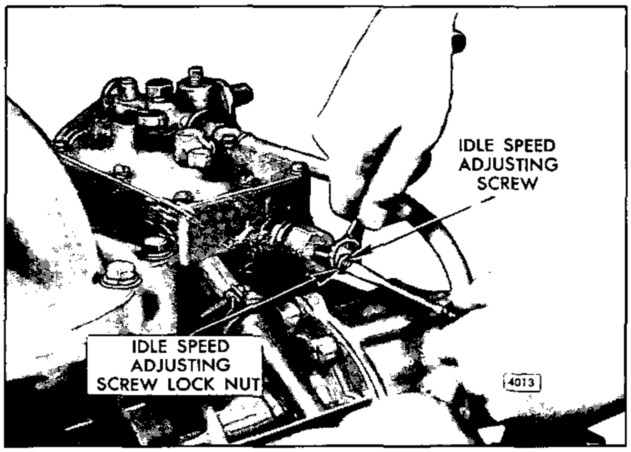


Fig. 9 – Adjusting Engine Idle Speed

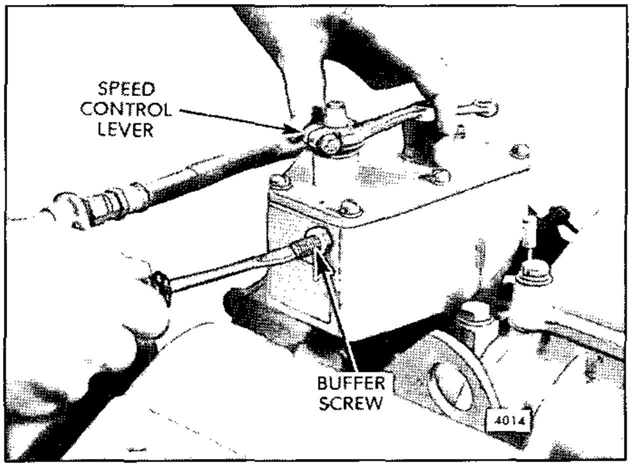


Fig. 10 – Adjusting Buffer Screw

d. Start the engine and recheck the no–load speed. Repeat the procedure, as necessary, to establish the no–load speed required.

Adjust Idle Speed

With the maximum no–load speed properly set, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 9) until the engine is operating at approximately 15 rpm below the recommended idle speed. The recommended idle

speed is 500–600 rpm, but may vary with the engine application.

If the engine has a tendency to stall during deceleration, install a new buffer screw. The current buffer screw uses a heavier spring and restricts the travel of the differential lever to the *off (no–fuel)* position.

2. Hold the idle screw and tighten the locknut.

3. Install the high–speed spring retainer cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in so it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 10).

NOTICE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no–load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the locknut.

After the governor adjustments are completed, adjust any supplementary governing device that may be used as outlined in Section 14.14.

8V–53 ENGINE

The limiting speed mechanical governor assembly is mounted on the front end of the blower (Fig. 11). The governor weight carrier shaft is attached to and driven by the left–hand helix rotor.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, set the governor gap as follows:

CAUTION: To avoid personal injury, if the governor gap adjustment is to be made with the engine in the vehicle, it is suggested that the fan assembly be removed due to the closeness of the fan blades to the engine governor.

1. Remove the high–speed spring retainer cover.

2. Back out the buffer screw until it extends approximately 5/8" from the locknut (Fig. 17).

NOTICE: Do not back the buffer screw out beyond the limits given, or the control link lever may disengage the differential lever.

3. Start the engine and loosen the idle speed adjusting screw or locknut, if used. Then adjust the idle screw to obtain the desired idle speed (Fig. 16). Hold the screw and tighten the locknut to hold the adjustment.

4. Run the engine until the proper operating temperature is reached, then stop the engine and remove the governor cover, lever assembly and the engine valve rocker covers. Discard the gaskets.

5. Start and run the engine, between 1100 and 1300 rpm, by manual operation of the differential lever. *Do not overspeed the engine.*

6. Check the gap between the low–speed spring cap and the high–speed spring plunger with a feeler gage (Fig. 12). The gap should be .002"–.004". If the gap setting is incorrect, reset the gap adjusting screw.

7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

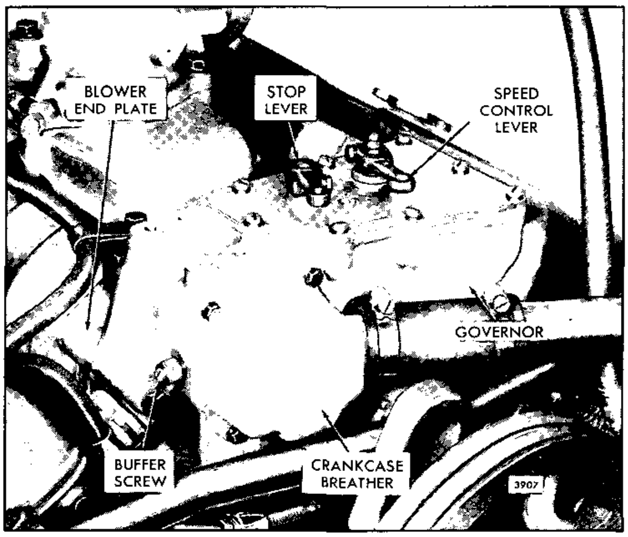


Fig. 11 – Limiting Speed Governor Mounting

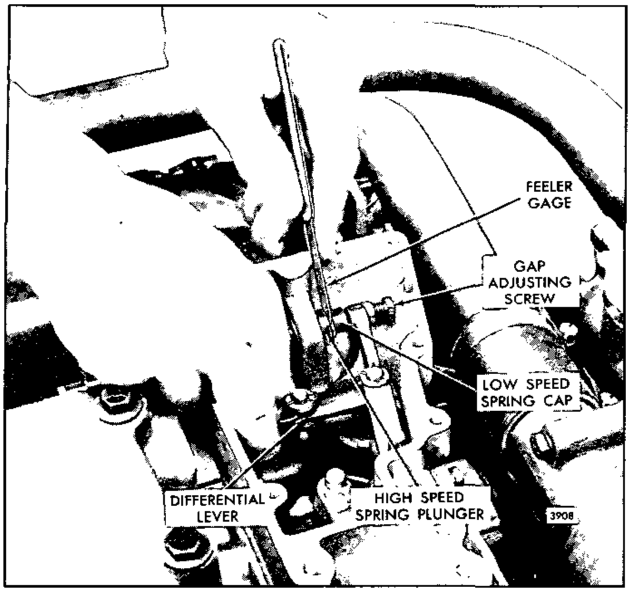


Fig. 12 – Checking Governor Gap

NOTICE: Governors which include a starting aid screw threaded into the end of the gap adjusting screw do not require a locknut as both screws incorporate a nylon patch in lieu of a locknut.

8. Recheck the gap with the engine operating between 1100 and 1300 rpm and readjust if necessary.

9. Stop the engine and, using a new gasket, install the governor cover.

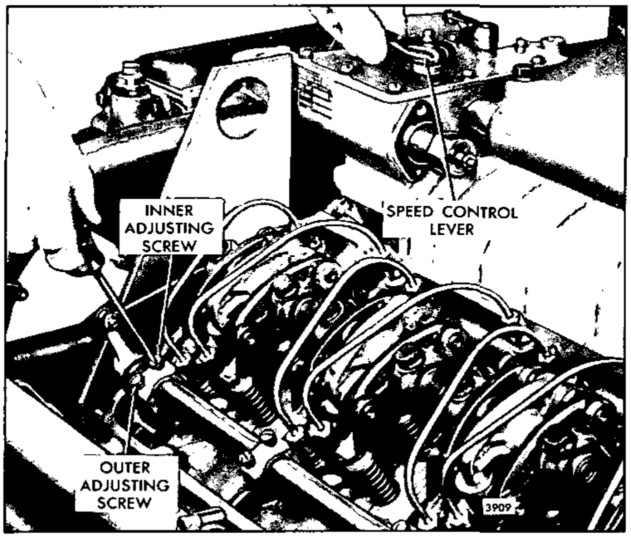


Fig. 13 – Positioning No. 1L Injector Rack Control Lever

10. If a starting aid screw is used, adjust it after the injector rack control levers are positioned.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the *full–fuel* position.
2. Governor low–speed gap closed.
3. High–speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the *full–fuel* position.

The letters "R" or "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect the linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until about 1/2″ of the threads (12–14 threads) projects from the locknut when the nut is against the high–speed plunger. This adjustment lowers the tension of the low–speed spring so it can be compressed, while closing the low–speed gap, without bending the fuel rods.

   NOTICE: A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

3. If not already done, back out the buffer screw as outlined in Step 2 under *Adjust Governor Gap.*

4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the *full–fuel* position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 1L injector rack control lever down (Fig. 13) until a slight movement of the control tube lever is observed or a step–up in effort to turn the screwdriver is noted. This will place the No. 1L injector in the *full–fuel* position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately

tighten both the inner and outer adjusting screws. This should result in placing the governor linkage and the control tube assembly in the same positions they will attain while the engine is running at full load as previously described.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

7. To be sure of the proper rack adjustment, hold the speed control lever in the *full–fuel* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the speed control lever is in the *full–fuel* position (Fig. 4). Hold the speed control lever in the *full–fuel* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 5), and when the pressure of the screwdriver is released, the control rack should "spring" back upward.

   The setting is sufficiently tight if the rack returns to its original position. If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw.

   The setting is too tight if, when moving the speed control lever from the *idle speed* to the *maximum speed* position, the injector rack becomes tight before the speed control lever reaches the end of its travel (stop under the governor cover). This will result in a step–up in effort to move the speed control lever to its *maximum speed* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 6 for the No. 1L injector rack control lever.

10. Insert the clevis pin in the fuel rod and the left cylinder bank injector control tube lever. Repeat the check on the No. 1L and No. 1R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.

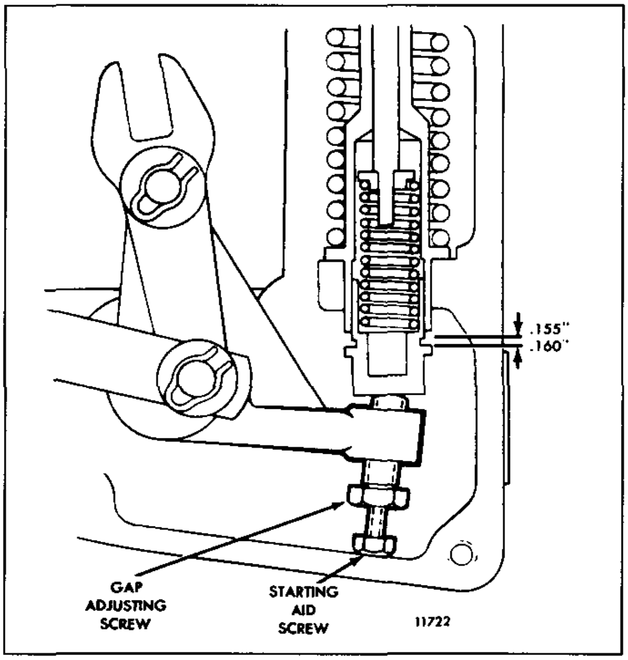


Fig. 14 – Adjust Starting Aid Screw

11. Manually hold the No. 1L injector rack in the *full–fuel* position and turn down the inner adjusting screw of the No. 2L injector rack control lever until the injector rack of the No. 2L injector has moved into the *full–fuel* position. Turn the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

12. Recheck the No. 1L injector rack to be sure it has remained snug on the ball end of the rack control lever while positioning the No. 2L injector rack. If the rack of the No. 1L injector has become loose, back off the inner adjusting screw slightly on the No. 2L injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

13. Position the No. 3L and 4L injector rack control levers as outlined in Steps 11 and 12.

14. Position the No. 2R, 3R and 4R injector racks as outlined above for the left cylinder bank.

15. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting of the engine.

- **CAUTION: Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the service technician must**

determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

16. Use new gaskets and reinstall the valve rocker covers.

Adjust Starting Aid Screw

The internal starting aid screw is threaded into the governor gap adjusting screw (Fig. 13). This screw is adjusted to position the injector racks at less than *full–fuel* when the governor speed control lever is in the *idle* position. The reduced fuel makes starting easier and reduces the amount of smoke on start–up.

NOTICE: The effectiveness of the starting aid screw will be eliminated if the speed control lever is advanced to wide open throttle during starting.

After the normal governor *running* gap of .0015″ has been set and the injector racks positioned, adjust the starting aid screw as follows:

1. With the engine stopped, place the governor stop lever in the *run* position and move the speed control lever to the *idle* position.

2. Hold the gap adjusting screw, to keep it from turning, and adjust the starting aid screw to obtain .330″ to .360″ clearance between the shoulder on the No. 1L injector rack clevis and the injector body, with the head of the starting aid screw against the governor wall.

   With the engine stopped, this adjustment will provide a gap of .155″ to .160″ between the high–speed spring plunger and the low–speed spring cap (Fig. 14).

3. Move the stop lever to the *stop* position, with the speed control lever still in the *idle* position, and return it to the *run* position.

4. Recheck the injector rack clevis–to–body clearance. Movement of the governor stop lever is to take–up clearances in the governor linkage. The clevis to body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjusting screw.

5. Start the engine and recheck the *running* gap (.0015″) and, if necessary, reset it. Then stop the engine.

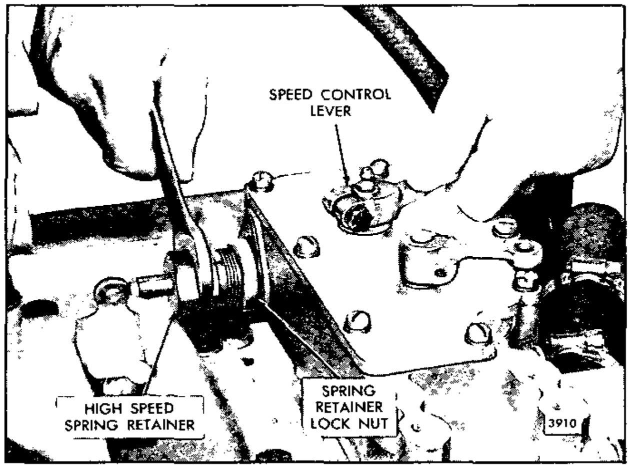


Fig. 15 – Adjusting Maximum No–Load Engine Speed

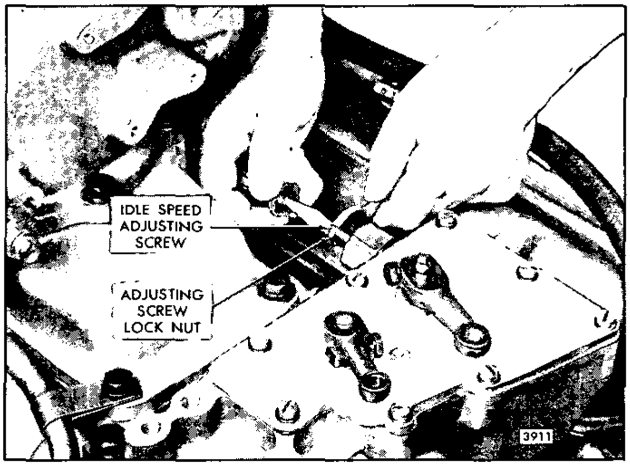


Fig. 16 – Adjusting Engine Idle Speed

Adjust Maximum No Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine name plate, set the maximum no–load speed as outlined below.

1. Loosen the locknut with a spanner wrench and back off the high–speed spring retainer several turns. Then start the engine and increase the speed slowly. If the speed exceeds the required no–load speed before the speed control lever reaches the end of its travel, back off the spring retainer a few additional turns.

2. With the engine at operating temperature and no load on the engine, place the speed control lever in the *maximum speed* position. Turn the high–speed spring retainer in (Fig. 14) until the engine is operating at the recommended no–load speed. Use an accurate hand

tachometer to determine the engine speed. The recommended speed droop is 150 rpm for governors with a full–load speed range of 2500–2800 rpm.

3. Hold the spring retainer and tighten the locknut.

Adjust Idle Speed

With the maximum no–load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 16) until the engine is operating at approximately 15 rpm below the recommended idle speed. *The recommended idle speed is 500 to 600 rpm, but may vary with special engine applications.*
2. Hold the idle screw and tighten the locknut.
3. Install the high–speed spring retainer cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly adjusted, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 17) so it contacts the differential lever as lightly as possible and still eliminates engine roll. *Do not increase the engine idle speed more than 15 rpm with the buffer screw.*
2. Recheck the maximum no–load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.
3. Hold the buffer screw and tighten the locknut to retain the adjustment.

After the governor adjustments are completed, adjust any supplementary governing device that may be used as outlined in Section 14.14.

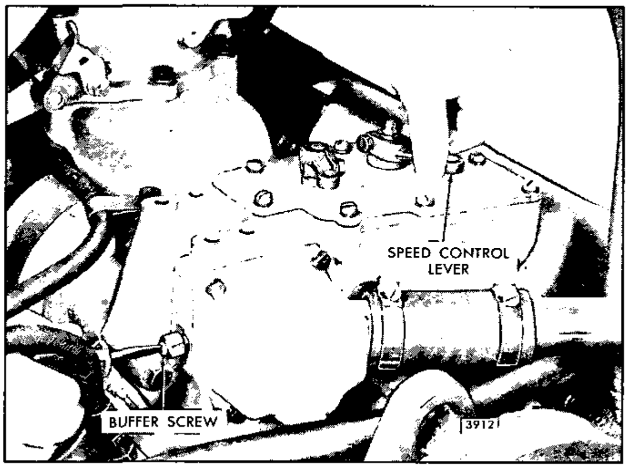


Fig. 17 – Adjusting Buffer Screw

LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT (VARIABLE LOW-SPEED)

IN-LINE AND 6V-53 ENGINES

The variable low–speed limiting speed mechanical governor used on In–line and 6V–53 highway vehicle engines is of the double–weight type. It is used where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain or liquids) and a 500 to 1200 rpm idle speed range is desired during auxiliary operation. A service kit is available to convert the short spring pack 6V–53 double weight limiting speed governor assembly to a cable operated variable low–speed limiting speed governor for 500 to 1600 rpm idle speed range auxiliary operations.

During highway operation, the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle, on the cable operated governor (Fig. 1), is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor (Fig. 2), the engine speed is changed to the speed required by increasing or decreasing the air supply pressure to the governor. The governor, then functions as a variable speed governor, maintaining a constant speed when the load is constantly changing, during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop, then turned ahead about one–quarter of a turn. The air operated governor's air supply pressure must be vented before resuming highway operations.

- **CAUTION: Failure to return the device to normal idle speed could result in loss of control of the engine at idle, causing possible personal injury.**

Governor identification is provided by a name plate attached to the governor housing. The letters V.L.S.–L.S. stamped on the name plate denote a variable low–speed limiting speed mechanical governor.

After adjusting the exhaust valves and timing the injectors, adjust the governor and position the injector rack control levers.

Adjust Governor Gap

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine, remove the two bolts and withdraw the spring housing. Discard the gasket.

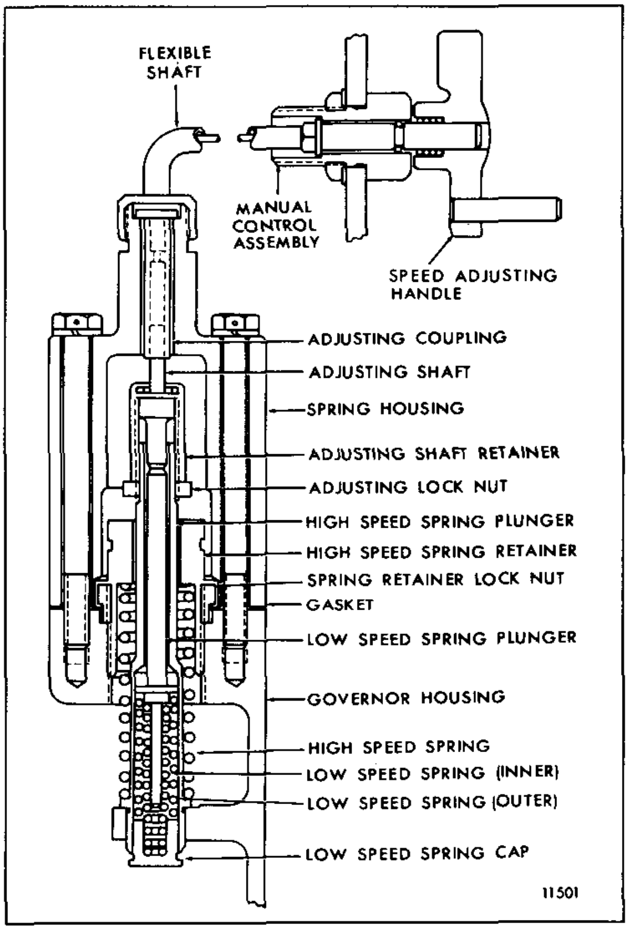


Fig. 1 – Cable Operated Governor Spring Housing and Components

2. Back out the buffer screw until it extends approximately 5/8″ from the locknut.
3. For *Cable Operated Governors* make a preliminary idle speed (normal highway idle speed) adjustment as follows (Fig. 1):
   a. Back out the variable low–speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer.
   b. Start the engine. Then, hold the locknut and loosen the low–speed adjusting shaft retainer.

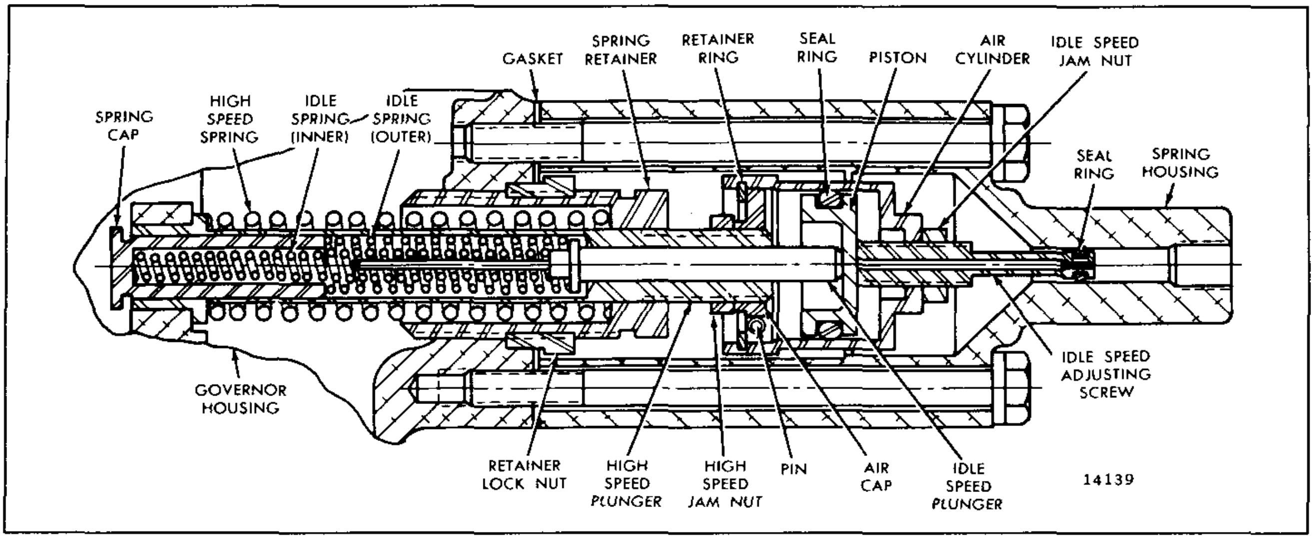


Fig. 2 – Air Operated Governor Spring Housing and Components

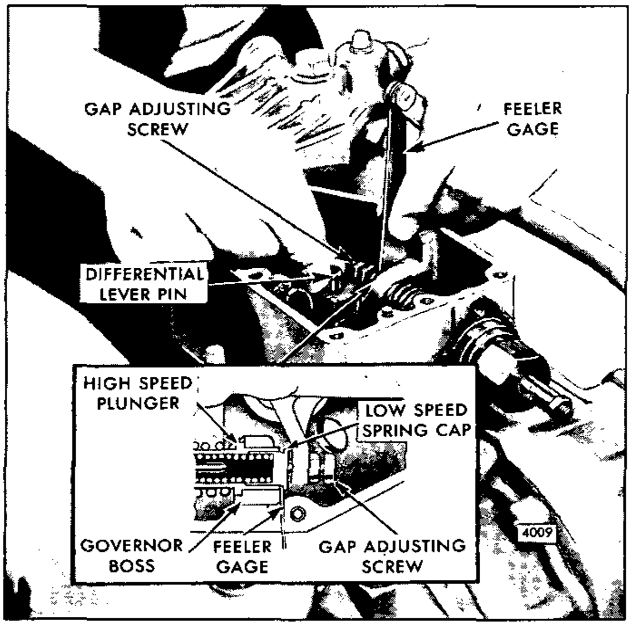


Fig. 3 – Adjusting Governor Gap

c. Adjust the retainer and shaft assembly to obtain the desired idle speed (500 rpm minimum). Then, hold the retainer and tighten the locknut to retain the adjustment.

   It may be necessary to use the buffer screw to *eliminate engine roll. Back out the buffer screw,* after the idle speed is established, to the previous setting (5/8").

d. Install the spring housing, using a new gasket. Tighten the attaching bolts.

4. For *Air Operated Governors* make a preliminary idle speed (normal highway idle speed) adjustment as follows (Figure 2):

   Adjust the maximum idle speed.

   a. Loosen the idle speed and high idle speed jam (lock) nuts.

   b. Turn the idle speed adjusting screw clockwise into the air cylinder, until the piston contacts the air cap. The air cylinder should be 2 or 3 threads from its position of maximum engagement with the high–speed spring plunger, to prevent the piston from contacting the high speed plunger before it contacts the air cap. *Do not force the idle speed adjusting screw.*

   c. Start the engine. With the speed control lever in the idle position, turn the air cylinder clockwise to raise the idle speed and counterclockwise to lower the idle speed.

   d. Lock the air cylinder to the high speed plunger with the jam nut in the position which provides the desired maximum idle speed.

   Adjust the minimum idle speed adjustment. *Make this adjustment after the maximum idle speed adjustment is completed.*

   a. Run the engine with the speed control lever in the idle speed position.

   b. Turn the idle speed adjusting screw counterclockwise to lower the idle speed and clockwise to raise the idle speed.

   c. Lock the idle speed adjusting screw with the jam nut, in the position which provides the desired minimum idle speed.

d. Stop the engine and lubricate the bore of the spring housing with engine lubricating oil.

e. Install the spring housing, using a new gasket. Tighten the attaching bolts.

5. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

6. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever. *Do not overspeed the engine.*

7. Check the gap between the low–speed spring cap and the high–speed spring plunger with a feeler gage (Fig. 1). The gap should be .002"–.004". If the gap setting is incorrect, reset the gap adjusting screw.

8. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

9. Recheck the gap with the engine operating between 1100 rpm and 1300 rpm and readjust, if necessary.

10. Reinstall the governor cover and lever assembly.

Position Injector Rack Control Levers

Position the injector rack control levers as outlined in Section 14.3.1 or 14.3.2.

- **CAUTION: Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

Adjust Maximum No–Load Engine Speed

Adjust the maximum no–load engine speed as outlined for the limiting speed mechanical governor in Section 14.3.1 or 14.3.2.

Adjust Idle Speed

Adjust the normal highway idle speed as follows:

With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, hold the locknut and loosen the variable low–speed adjusting shaft retainer. Adjust the retainer and shaft assembly to obtain a minimum of 500 rpm.

It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

Adjust Buffer Screw

Adjust the buffer screw as outlined in Section 14.3.1 or 14.3.2.

After the governor tune–up is completed, install the variable low–speed adjuster coupling and spring housing. Center the coupling before securing the spring housing to the governor. Install the flexible shaft and manual control assembly.

LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT (FAST IDLE CYLINDER)

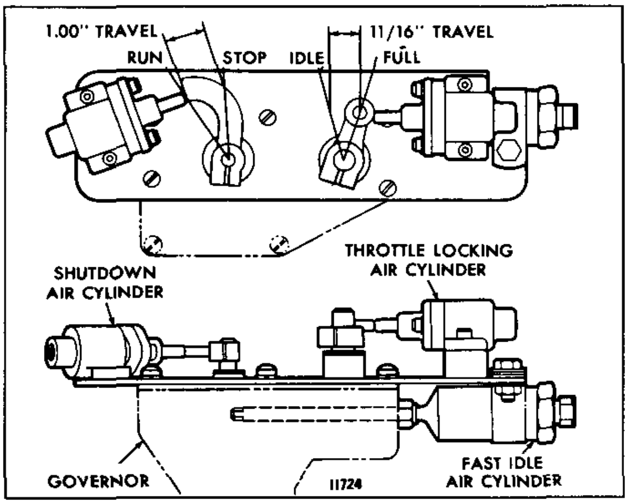


Fig. 1 – Governor with Fast Idle Cylinder

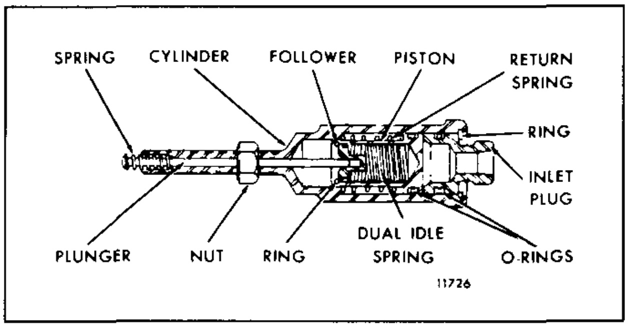


Fig. 2 – Fast Idle Air Cylinder

The limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Fig. 1). An engine shutdown air cylinder, if used, is also mounted on the governor cover.

The fast idle air cylinder and the throttle locking air cylinder are actuated at the same time by air from a common air line.

The engine shutdown air cylinder is connected to a separate air line. The air supply for the fast idle air cylinder is usually controlled by an air valve actuated by an electric solenoid. The fast idle system should be installed so that it will function only when the parking brake system is in operation to make it tamper–proof.

The vehicle accelerator–to–governor throttle linkage is connected to a yield link so the operator cannot overcome the force of the air cylinder holding the speed control lever in the idle position while the engine is operating at the single fixed high idle speed.

Operation

During highway operation, the governor functions as a limiting speed governor.

For operation of auxiliary equipment, the vehicle is stopped and the parking brake set. Then, with the engine running, the low speed switch is placed in the ON position. When the fast idle air cylinder is actuated, the force of the dual idle spring (Fig. 2) is added to the force of the governor low–speed spring, thus increasing the engine idle speed.

The governor now functions as a constant speed governor at the high idle speed setting, maintaining a near constant engine speed regardless of the load within the capacity of the engine. The fast idle system provides a single fixed high idle speed that is not adjustable, except by disassembling the fast idle air cylinder and changing the dual idle spring. As with all mechanical governors, when load is applied, the engine speed will be determined by the governor droop.

Adjust Governor

Adjust the governor as outlined in Section 14.3.2. However, before adjusting the governor gap, back out the de–energized fast idle air cylinder until it will not interfere with the governor adjustments. After the normal idle speed setting is made, adjust the de–energized fast idle air cylinder as follows:

1. Turn in the fast idle cylinder assembly until an increase of idle speed is noted. The increase in idle speed should not exceed 15 rpm. Tighten the fast idle jam nut.

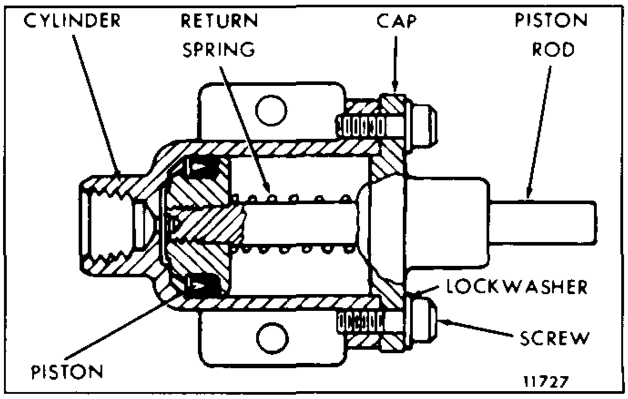


Fig. 3 – Throttle Locking Air Cylinder

2. Lock the governor throttle in the idle position and apply full shop air pressure to the fast idle air cylinder. The engine idle speed must increase 250–800 rpm, depending upon the dual idle spring used.

The throttle locking air cylinder is adjusted on its mounting bracket so it will lock the throttle in the idle position when it is activated, but will not limit the throttle movement when not activated.

VARIABLE SPEED MECHANICAL GOVERNOR (OPEN LINKAGE) AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINES

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor (Fig. 1) and the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Preliminary Governor Adjustments

1. Clean the governor linkage and lubricate the ball joints and bearing surfaces with clean engine oil.

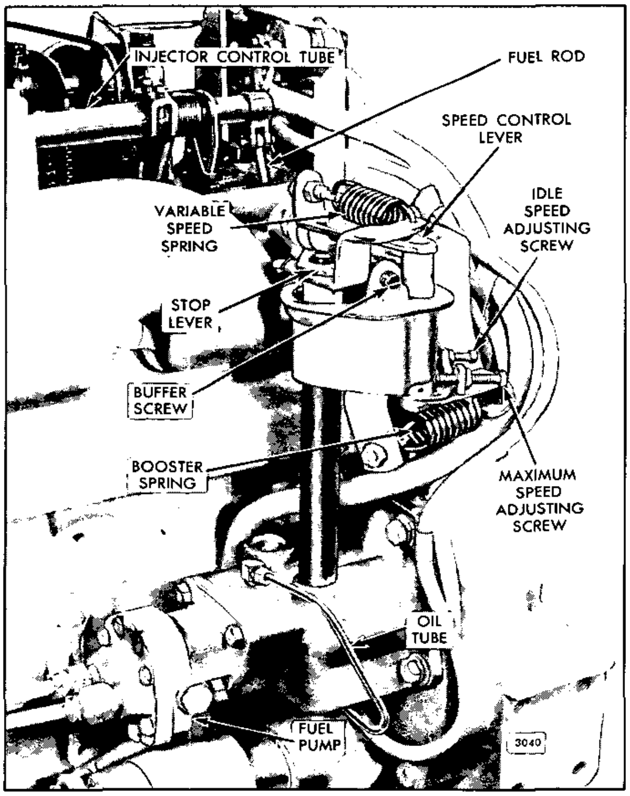


Fig. 1 – Variable Speed Open Linkage Governor Mounted on Engine

2. Back out the buffer screw until it projects 9/16" from the boss on the control housing.
3. Back out the booster spring eyebolt until it is flush with the outer locknut.

Adjust Variable Speed Spring Tension

1. Adjust the variable speed spring eyebolt until 1/8" of the threads project from the outer locknut (Fig. 2). This setting of the eyebolt will produce approximately 7% droop in engine speed from no load to full load.
2. Tighten both locknuts to retain the adjustment.

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load. Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Clean and remove the valve rocker cover. Discard the gasket.

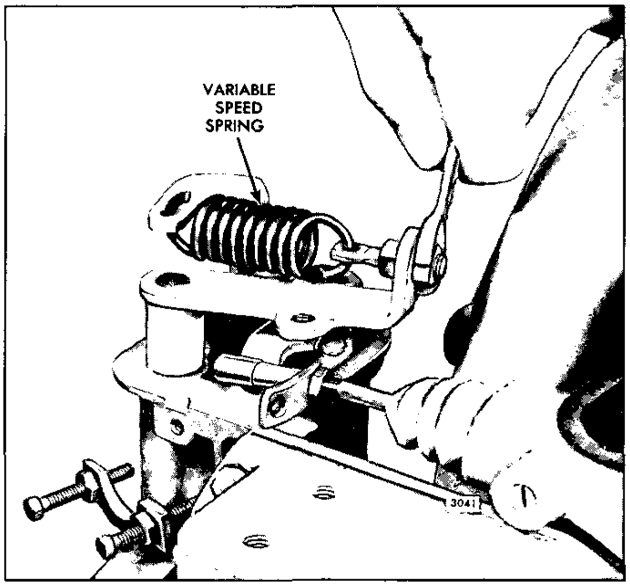


Fig. 2 – Adjusting Governor Spring Eyebolt

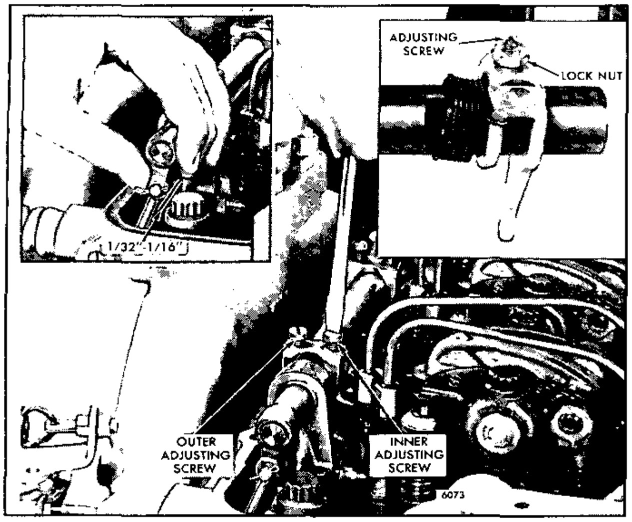


Fig. 3 – Adjusting Injector Rack Control Lever Adjusting Screws

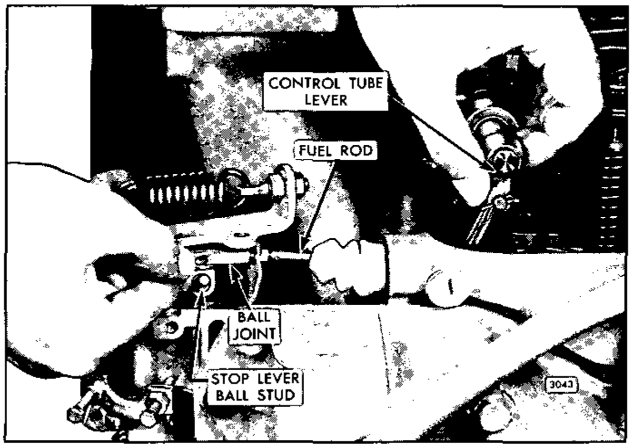


Fig. 4 – Adjusting Fuel Rod Length

2. Disconnect the fuel rod at the stop lever.

3. Loosen all of the injector rack control lever adjusting screws. Be sure all of the injector rack control levers are free on the injector control tube.

4. Move the speed control lever to the *maximum* speed position.

5. Move the rear injector control rack into the *full–fuel* position and note the clearance between the fuel rod and the cylinder head bolt. The clearance should be 1/32" or more. If necessary, readjust the injector rack adjusting screws until a clearance of at least 1/32" to 1/16" exists. Tighten the adjustment screws or screw and locknut (Fig. 3).

6. Loosen the nut which locks the ball joint on the fuel rod. Hold the fuel rod in the *full–fuel* position and adjust the ball joint until it is aligned and will slide on the ball stud on the stop lever (Fig. 4). Position the shutdown cable clip and tighten the fuel rod locknut to retain the adjustment.

7. Check the adjustment by pushing the fuel rod toward the engine and make sure the injector control rack is in the *full–fuel* position. If necessary, readjust the fuel rod. On units having the governor on the opposite side of the control rack, be sure the control rack lever will not contact the rocker cover.

8. Manually hold the rear injector rack in the *full–fuel* position, with the lever on the injector control tube. Turn the adjusting screw of the adjacent injector rack control lever until the injector rack moves into the *full–fuel* position.

   On the Two Screw Assembly, turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws. On the *One Screw and Locknut Assembly,* turn the adjusting screw until a slight roll–up on the injector rack clevis is observed or an increase in effort to turn the screwdriver is noted, then securely lock the adjusting screw locknut.

   NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

9. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose, back off the adjusting screw slightly on the adjacent injector rack control lever. When the settings are correct, the racks of all injectors must be snug on the ball end of their respective control levers.

10. Position the remaining injector rack control levers as outlined in Steps 8 and 9.

- ***CAUTION:* Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* posiiton. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

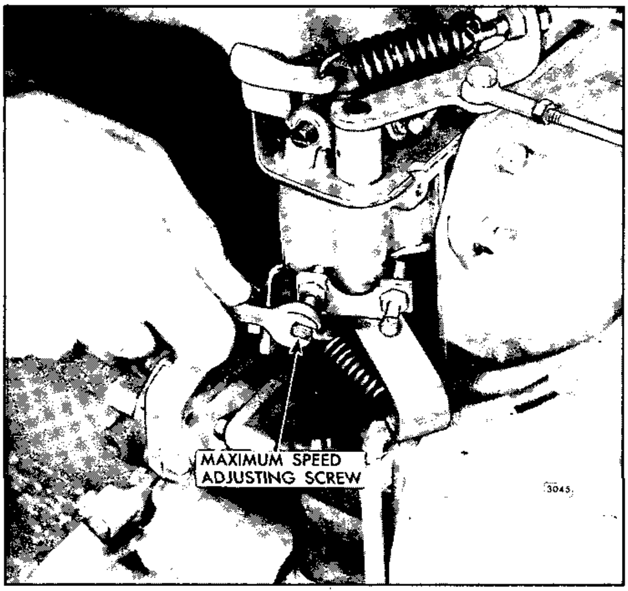


Fig. 5 – Adjusting Maximum No–Load Engine Speed

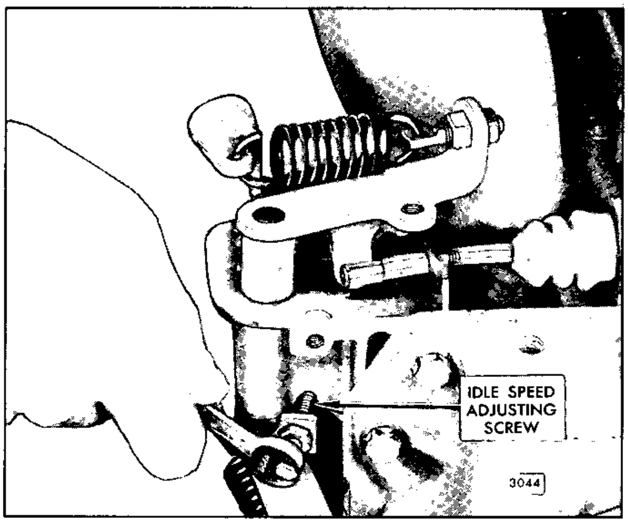


Fig. 6 – Adjusting Idle Speed

Adjust Maximum No–Load Speed

1. With the engine running, move the speed control lever to the maximum speed position. Use an accurate tachometer to determine the no–load speed of the engine. Do not overspeed the engine.

2. Loosen the locknut and adjust the maximum speed adjusting screw (Fig. 6) until the required no–load speed is obtained.

3. Hold the adjusting screw and tighten the locknut.

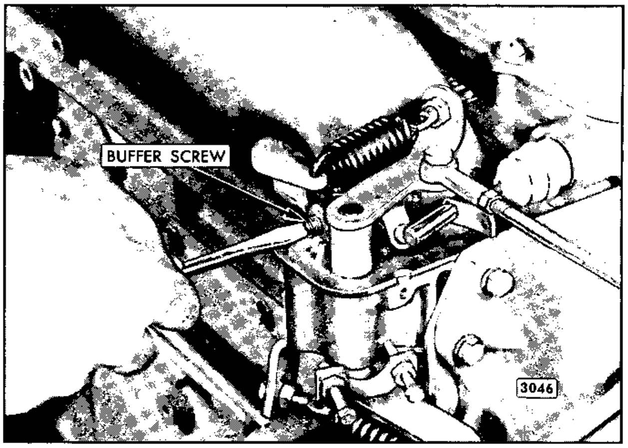


Fig. 7 – Adjusting Buffer Screw

Adjust Engine Idle Speed

1. Make sure the stop lever is in the run position and place the speed control lever in the idle position.

2. With the engine running at normal operating temperature, loosen the locknut and turn the idle speed adjusting screw (Fig. 6) until the engine idles at the recommended speed. The recommended idle speed is 500 rpm. However, the idle speed may vary with special engine applications.

3. Hold the idle speed adjusting screw and tighten the locknut.

Adjust Buffer Screw

1. With the engine running at idle speed, turn the buffer screw in (Fig. 7) so that it contacts the stop lever as lightly as possible and still eliminates engine roll. Do not raise the engine idle speed more than 20 rpm with the buffer screw.

2. Check the maximum no–load speed to make sure it has not increased over 25 rpm by the buffer screw setting.

Adjust Governor Booster Spring

The governor booster spring is used on some engines to reduce the force necessary to move the speed control lever from the idle speed position to the maximum speed position. Adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Reduce the tension on the booster spring, if not previously reduced, to the minimum by backing off the outer locknut (Fig. 8) until the end of the booster spring eyebolt is flush with the end of the nut.

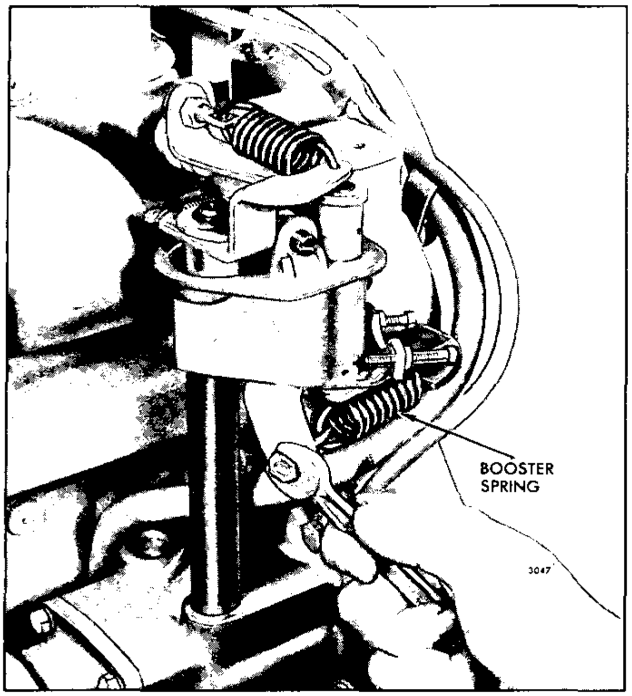


Fig. 8 – Adjusting Booster Spring

3. Adjust the eyebolt in the slot in the bracket so that an imaginary line through the booster spring will align with an imaginary center line through the speed control shaft. Secure the locknuts on the eyebolt to retain the adjustment.

4. Move the speed control lever to the maximum speed position and note the force required. To reduce the force, back off the inner locknut and tighten the outer locknut to increase the tension on the booster spring. Before tightening the locknuts, reposition the booster spring as in Step 3.

The setting is correct when the speed control lever can be moved from the idle speed position to the maximum speed position with a constant force, while the engine is running, and when released it will return to the idle speed position.

Adjust Engine Speed Droop

The adjustment of the spring tension as outlined under *Adjust Variable Speed Spring Tension* will result in approximately 7% droop from the maximum no–load speed to the full–load speed. This is the optimum droop setting for most applications. However, the droop may be changed as necessary, for a particular engine application.

1. Lower the speed droop by increasing the spring tension.

2. Raise the speed droop by decreasing the spring tension.

A change in the variable speed spring tension will change the engine idle speed and maximum no–load speed, which must also be readjusted.

VARIABLE SPEED MECHANICAL GOVERNOR (ENCLOSED LINKAGE) AND INJECTOR RACK CONTROL ADJUSTMENT

IN–LINE ENGINES

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact.

After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Back out the external starting aid screw.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.
2. Back out the buffer screw until it extends approximately 5/8″ from the locknut.

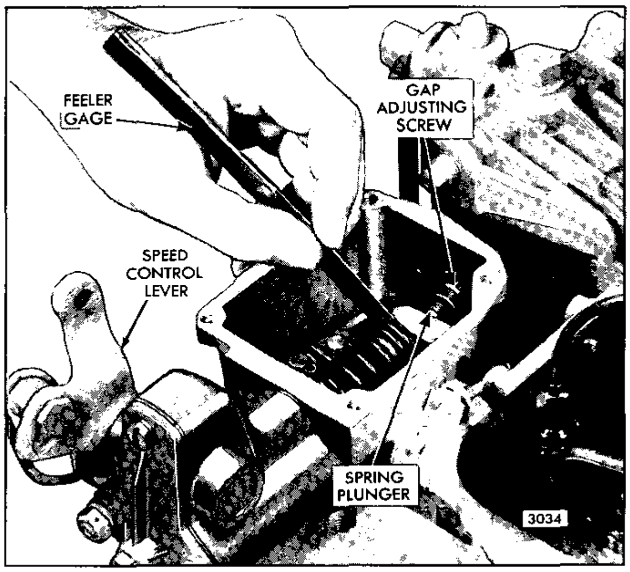


Fig. 1 – Checking Governor Gap

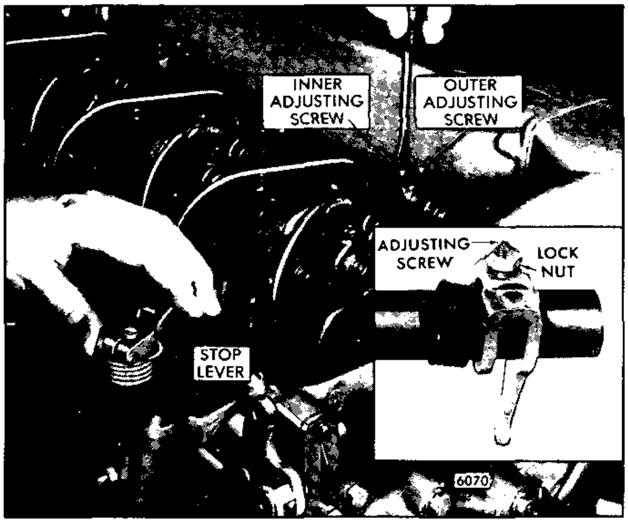


Fig. 2 – Positioning the Rear Injector Rack Control Lever

3. Clean and remove the governor cover and valve rocker cover. Discard the gaskets.
4. Place the speed control lever in the maximum speed position (Fig. 1).
5. Insert a .006″ feeler gage between the spring plunger and the plunger guide (Fig. 1). If required, loosen the locknut and turn the gap adjusting screw in or out until a slight drag is noted on the feeler gage.
6. Hold the adjusting screw and tighten the locknut. Check the gap and readjust, if necessary.
7. Use a new gasket and reinstall the governor cover as follows:
   a. Place the cover on the governor housing, with the pin in the throttle shaft assembly entering the slot in the differential lever.
   b. Install the four cover screws and lock washers finger tight.
   c. Pull the cover assembly in a direction away from the engine, to take up the slack, and tighten the cover screws. This step is required since no dowels are used to locate the cover on the housing.

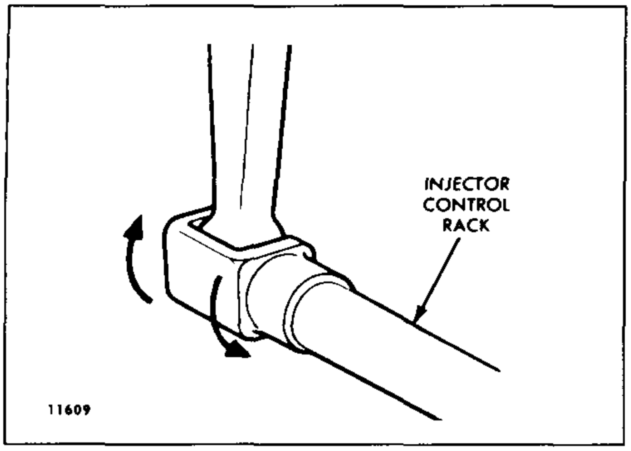


Fig. 3 – Checking Rotating Movement of Injector Control Rack

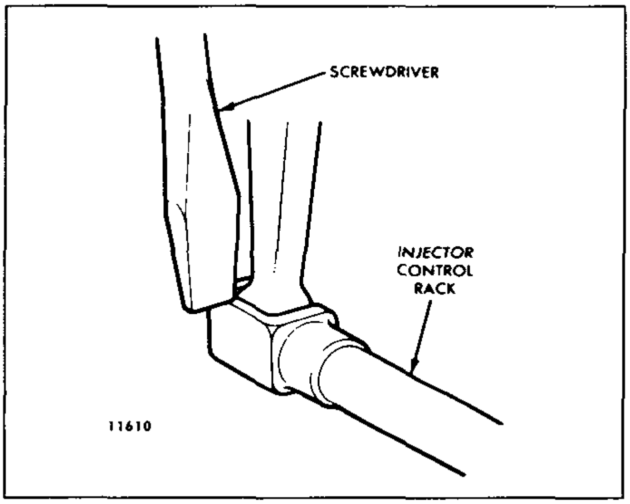


Fig. 4 – Checking Injector Control Rack Spring

Position Injector Rack Control Levers

The position of the injector control rack levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector control rack levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.
2. Stop lever in the *run* position.
3. Injector fuel control racks in the *full–fuel* position.

Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Loosen all of the inner and outer injector rack control lever adjusting screws or the adjusting screws and locknuts (Fig. 2). Be sure all of the levers are free on the injector control tube.
2. Move the speed control lever to the *maximum speed* position.
3. Move the stop lever to the *run* position and hold it in that position with light finger pressure.

   Two Screw Assembly

   a. Turn the inner adjusting screw of the rear injector rack control lever down until a slight movement of the control tube is observed or a step–up in effort to turn the screwdriver is noted. This will place the rear injector rack in the *full–fuel* position.

   b. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

   c. Then alternately tighten both the inner and outer adjusting screws.

   One Screw and Locknut Assembly

   a. Tighten the adjusting screw of the rear injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted.

   b. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the rear injector rack in the *full–fuel* position.

   This should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

4. To be sure of proper rack adjustment, hold the stop lever in the *run* position and press down on the injector rack with a screwdriver or finger tip and note "rotating" movement of the injector control rack (Fig. 3). Hold the stop lever in the *run* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 4) and, when the pressure of the screwdriver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly,* back off the outer adjusting screw slightly and tighten the inner adjusting screw. To

correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

The setting is too tight if, when moving the stop lever from the *stop* to the *run* position, the injector rack becomes tight before the stop lever reaches the end of its travel. This will result in a step–up in effort required to move the stop lever to the *run* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend).

If the rack is found to be too tight with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw. To correct this condition with the *One Screw and Locknut Assemsbly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

5. Manually hold the rear injector control rack in the *full–fuel* position with the lever on the injector control tube and proceed as follows:

Two Screw Assembly

a. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the *full–fuel* position and the inner adjusting screw is bottomed on the injector control tube.

b. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

c. Then alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly

a. Tighten the adjusting screw of the adjacent injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted.

b. Securely lock the adjusting screw locknut.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

6. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose with the *Two Screw Assembly,* back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting screw. With the *One Screw and Locknut Assembly,* turn the adjusting screw counterclockwise slightly until the rear injector rack returns to its *full–fuel* position and secure the adjusting screw locknut.

When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

7. Position the remaining injector rack control levers as outlined in Steps 4, 5 and 6.

8. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the *full–fuel* position, check each control rack as in Step 4. All of the control racks must have the same "spring" condition with the control tube lever in the *full–fuel* position.

9. Insert the clevis pin in the fuel rod and the injector control tube levers.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the service technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* posiiton. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

10. Use a new gasket and reinstall the valve rocker cover.

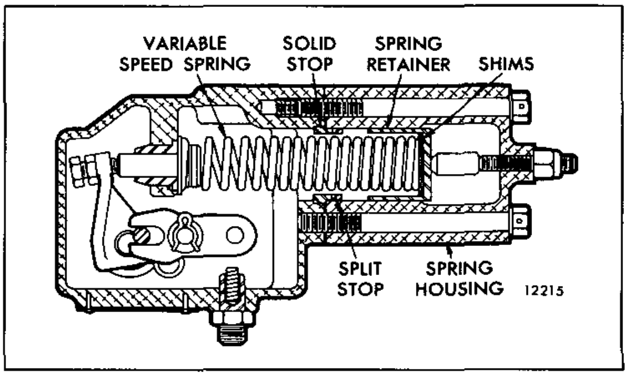


Fig. 5 – Location of Shims and Stops

Adjust Maximum No–Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the option plate, the maximum no–load speed may be set as follows:

1. Refer to Fig. 8 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the two attaching bolts and withdraw the variable speed spring housing and the variable speed spring retainer located inside of the housing.

3. Refer to Table 1 and determine the stops or shims required for the desired full–load speed (Fig. 5). Do not use more than four thick and one thin shim. *A split stop can only be used with a solid stop.*

4. Install the variable speed spring retainer and housing and tighten the two bolts.

5. Connect the booster spring and stop lever spring. Start the engine and recheck the maximum no–load speed.

6. If required, add shims to obtain the necessary operating speed. For each .001″ in shims added, the operating speed will increase approximately 2 rpm.

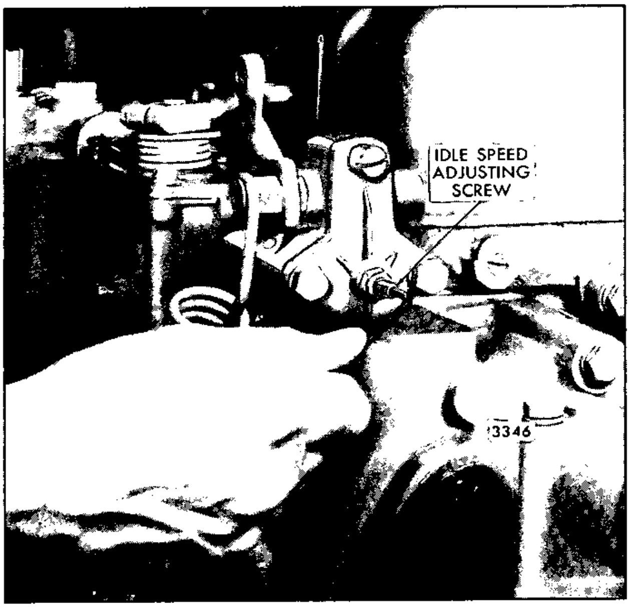


Fig. 6 – Adjusting Idle Speed

Full Load Speed RPM	STOPS		SHIMS
	Solid Ring	Split Ring	
2575-2800	0	0	As Required
2101-2575	1	0	As Required
1701-2100	1	1	As Required
1200-1700	1	2	As Required

TABLE 1

Fig. 7 – Adjusting Buffer Screw

If the maximum no–load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked. Governor stops are used to limit the compression of the governor spring which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no–load speed properly set, adjust the idle speed as follows:

1. Place the stop lever in the *run* position and the speed control lever in the *idle* position.

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the locknut and turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed (Fig. 6). The recommended idle speed is 550 rpm, but may vary with special engine applications.

4. Hold the idle speed adjusting screw and tighten the locknut.

Adjust Buffer Screw

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 7) so that it contacts the differential lever as lightly as possible and still eliminates engine roll. *Do not increase the engine idle speed more than 15 rpm with the buffer screw.*

2. Hold the buffer screw and tighten the locknut.

Adjust Booster Spring

With the engine idle speed set, adjust the booster spring as follows:

1. Move the speed control lever to the *idle* speed position.

2. Refer to Fig. 8 and loosen the booster spring retaining nut on the speed control lever. Loosen the locknuts on the eyebolt at the opposite end of the spring.

3. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the bolt, lever shaft and eyebolt. Hold the bolt and tighten the locknut.

4. Start the engine and move the speed control lever to the *maximum speed* position and release it. The lever should return to the *idle speed* position. If it does not, reduce the booster spring tension. If it does, continue to increase the spring tension until the point is reached where it will not return to idle. Then reduce the spring tension until the lever does return to idle and tighten the locknuts on the eyebolt. This setting will result in the minimum force required to operate the speed control lever.

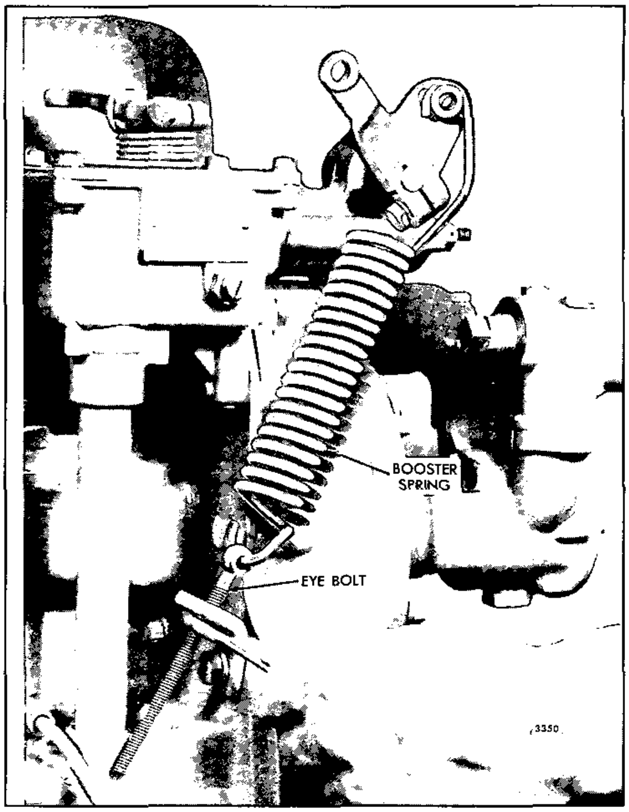


Fig. 8 – Adjusting Booster Spring

5. Connect the linkage to the governor levers.

If the engine is equipped with a supplementary governing device, refer to Section 14.14 and adjust it at this time.

VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

6V-53 ENGINES

The variable speed mechanical governor assembly is mounted at the rear of the 6V engine, between the flywheel housing and the blower (Fig. 1). The governor is driven by the right-hand blower rotor drive gear.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and the injector rack control levers.

NOTICE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.
2. Back out the buffer screw until it extends approximately 5/8" from the lock nut.
3. Clean and remove the governor cover and the valve rocker covers. Discard the gaskets.
4. Place the speed control lever in the maximum speed position.

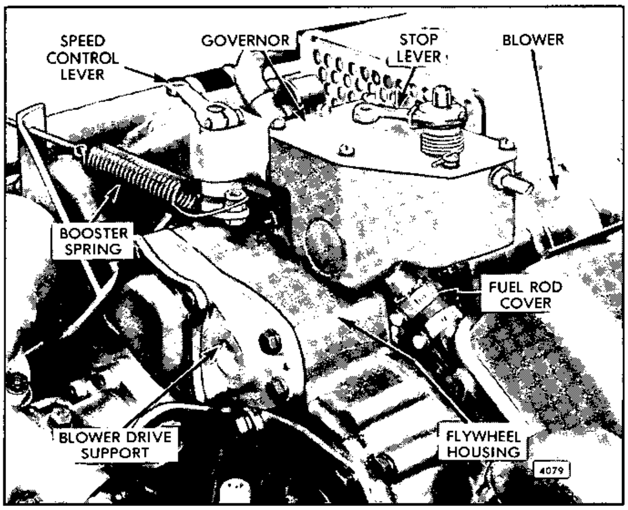


Fig. 1 – Variable Speed Governor Mounting

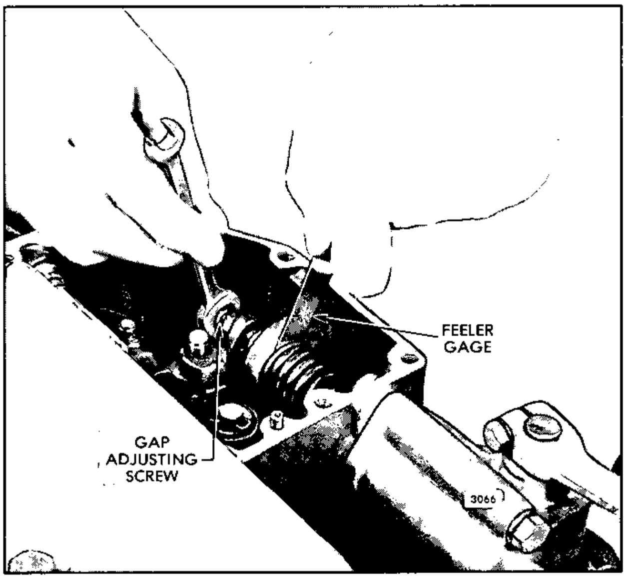


Fig. 2 – Adjusting Governor Gap

5. Insert a .006" feeler gage between the spring plunger and the plunger guide as shown in Fig. 2. If required, loosen the lock nut and turn the adjusting screw in or out until a slight drag is noted on the feeler gage.
6. Hold the adjusting screw and tighten the lock nut. Check the gap and readjust if necessary.
7. Use a new gasket and install the governor cover.

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Current engines use spring-loaded injector control tube assemblies which have a yield spring at each injector rack control lever and only one screw and lock nut to keep each injector rack properly positioned. Adjust the single screw and lock nut on each injector rack control lever the same as for the two screw rack control lever.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Stop lever in the RUN position.

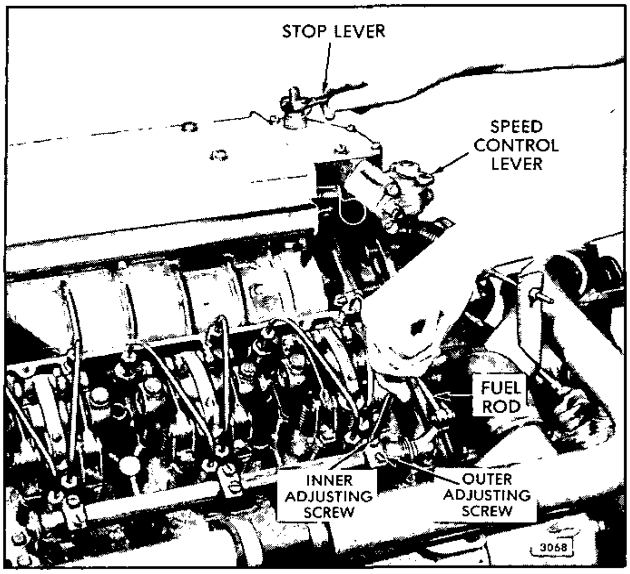


Fig. 3 – Positioning No. 3L Injector Rack Control Lever

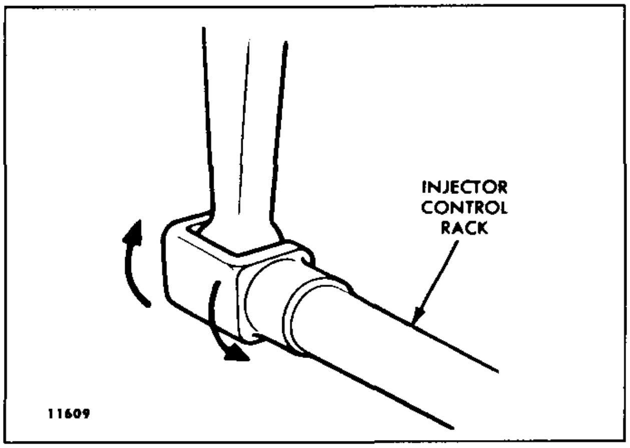


Fig. 4 – Checking Rotating Movement of Injector Control Rack

3. Injector fuel control racks in the *full–fuel* position.

The letters R or L indicate the injector location in the right or left cylinder bank as viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 3L injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

2. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

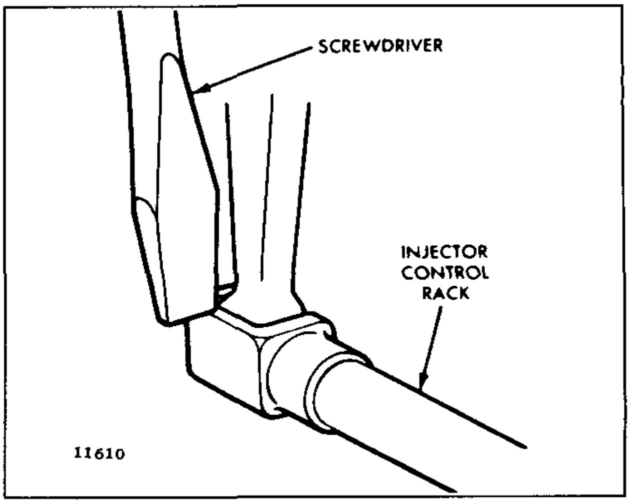


Fig. 5 – Checking Injector Control Rack Spring

3. Move the speed control lever to the maximum speed position.

4. Move the stop lever to the *run* position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 3L injector rack control lever down (Fig. 3) until a slight movement of the control tube is observed, or a step–up in effort to turn the screw driver is noted. This will place the No. 3L injector rack in the *full–fuel* position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

The above steps should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

5. To be sure of proper rack adjustment, hold the stop lever in the *run* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack (Fig. 4).

Hold the stop lever in the *run* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 5) and when the pressure of the screwdriver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer

adjusting screw slightly and tighten the inner adjusting screw. The setting is too tight if, when moving the stop lever from the *stop* to the *run* position, the injector rack becomes tight before the governor stop lever reaches the end of its travel. This will result in a step–up in effort required to move the stop lever to the *run* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

6. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

7. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 3R injector rack control lever as previously outlined in Step 4 for the No. 3L control lever.

8. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the 3L and 3R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

9. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rods and the injector control tube levers, hold the injector control racks in the *full–fuel* position by means of the lever on the end of the control tube and proceed as follows:

   a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the *full–fuel* position).

   b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

   c. While still holding the control tube lever in the *full–fuel* position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 5. Tighten the screws.

NOTICE: Once the No. 3L and No. 3R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

10. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the *full–fuel* position, check each control rack as in Step 5. All of the control racks must have the same "spring" condition with the control tube lever in the *full–fuel* position.

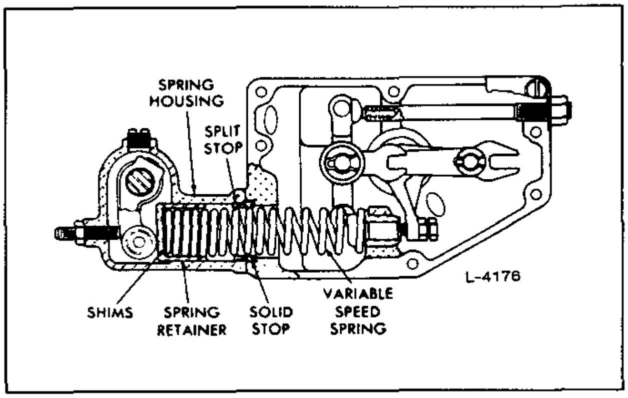


Fig. 6 – Location of Shims and Stops

11. Insert the clevis pin in the fuel rods and the injector control tube levers.

12. Use new gaskets and install the valve rocker covers.

Adjust Maximum No–Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine option plate, the maximum no–load speed may be set as follows:

Start the engine and after it reaches normal operating temperature, determine the maximum no–load speed of the engine with an accurate tachometer. Then stop the engine and make the following adjustments, if required.

1. Refer to Fig. 9 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the variable speed spring housing and the spring retainer, located inside of the housing from the governor housing.

3. Refer to Table 1 and determine the stops or shims required for the desired full–load speed. A split stop can only be used with a solid stop (Fig. 6).

4. Install the variable speed spring retainer and housing and tighten the two bolts.

Full-Load Speed	Stops		Shims*
	Solid	Split	
1200-2100	1	1	As Required
2100-2500	1	0	As Required
2500-2800	0	0	As Required

*Maximum amount of shims .325"

1 TABLE 1

5. Connect the booster spring and the stop lever spring. Start the engine and recheck the maximum no–load speed.

6. If required, add shims to obtain the necessary operating speed. For each .001" in shims added, the operating speed will increase approximately 2 rpm.

If the maximum no–load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no–load speed properly adjusted, adjust the idle speed as follows:

1. Place the stop lever in the *run* position and the speed control lever in the *idle* position.

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the lock nut and turn the idle speed adjusting screw (Fig. 7) until the engine is operating at approximately 15 rpm below the recommended idle speed. The recommended idle speed is 550 rpm, but may vary with special engine applications.

4. Hold the idle speed adjusting screw and tighten the lock nut.

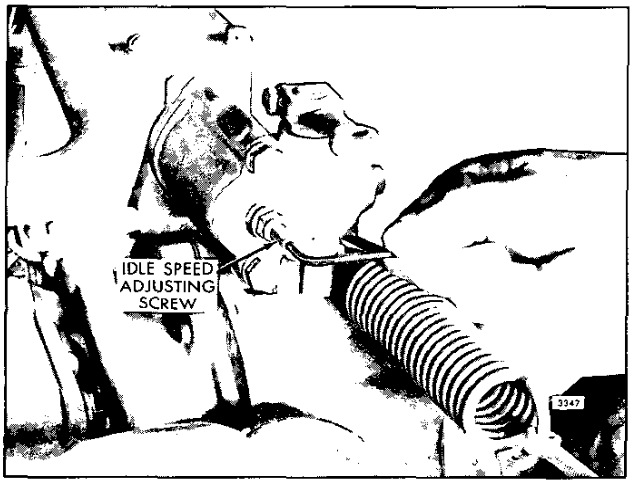


Fig. 7 – Adjusting Idle Speed

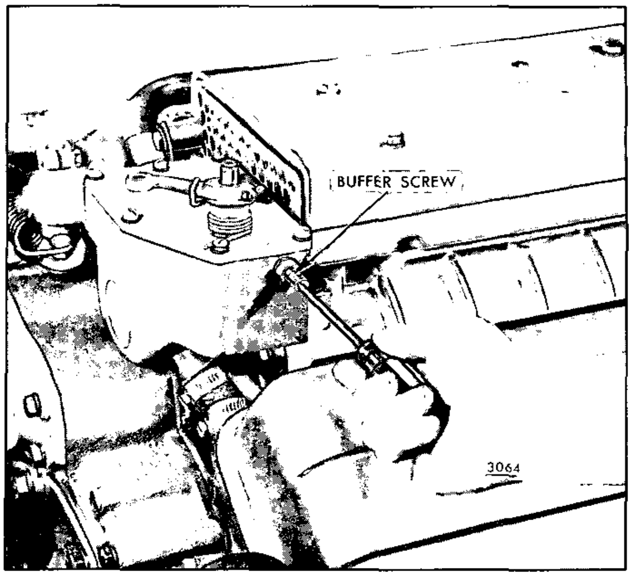


Fig. 8 – Adjusting Buffer Screw

Adjust Buffer Screw

With the engine idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 8) so that it contacts the differential lever as lightly as possible and still eliminates engine roll. *Do not raise the engine idle speed more than 15 rpm with the buffer screw.*

2. Hold the buffer screw and tighten the lock nut.

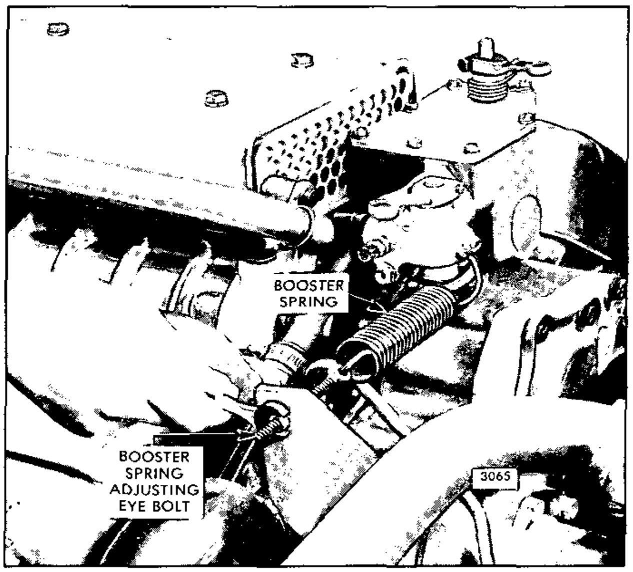


Fig. 9 – Adjusting Booster Spring

Adjust Booster Spring

With the idle speed set, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Refer to Fig. 9 and loosen the booster spring retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the opposite end of the booster spring.

3. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the center of the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock nut.

4. Start the engine and move the speed control lever to the maximum speed position and release it. The speed control lever should return to the idle position. If it does not, reduce the tension on the booster spring. If the lever does return to the idle position, continue to increase the spring tension until the point is reached that it will not return to idle. Then reduce the tension until it does return to idle and tighten the lock nut on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

5. Connect the linkage to the governor levers.

8V-53 ENGINES

The variable speed mechanical governor assembly is mounted at the front end of the 8V engine (Fig. 10). After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.

2. Back out the buffer screw until it extends approximately 5/8″ from the lock nut.

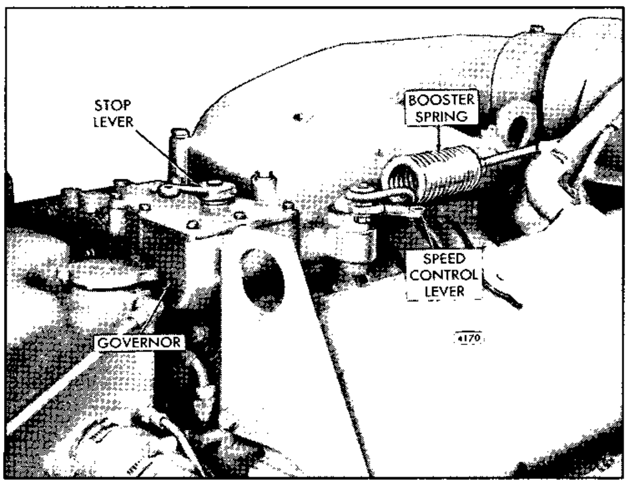


Fig. 10 – Variable Speed Governor Mounting

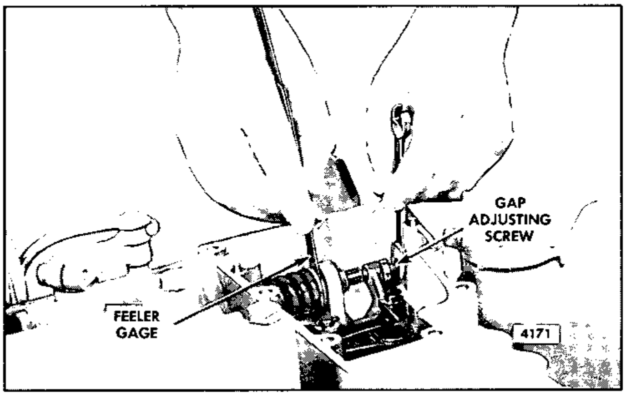


Fig. 11 – Adjusting Governor Gap

3. Clean and remove the governor cover and the valve rocker covers. Discard the gaskets.

4. Place the speed control lever in the maximum speed position.

5. Insert a .006″ feeler gage between the spring plunger and the plunger guide as shown in Fig. 11. If required, loosen the lock nut and turn the adjusting screw in or out until a slight drag is noted on the feeler gage.

6. Hold the adjusting screw and tighten the lock nut. Check the gap and readjust, if necessary.

7. Use a new gasket and install the governor cover.

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

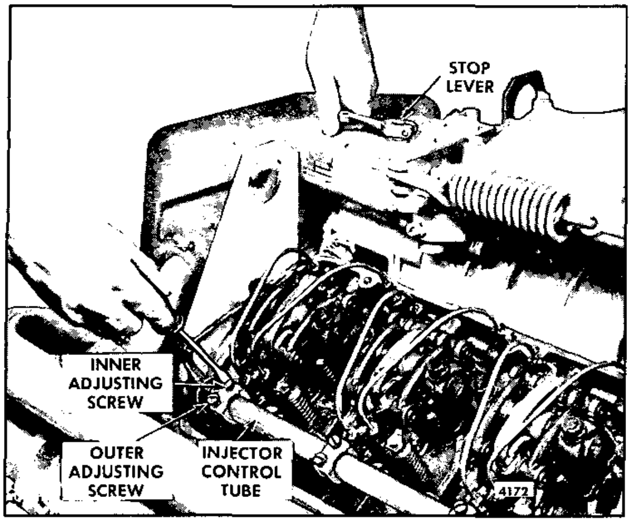


Fig. 12 – Positioning No. 1L Injector Rack Control Lever

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Stop lever in the RUN position.
3. Injector fuel control racks in the *full–fuel* position.

The letters R or L indicate the injector location in the right or left cylinder bank as viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.
2. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.
3. Move the speed control lever to the maximum speed position.
4. Move the stop lever to the *run* position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 1L injector rack control lever down (Fig. 12) until a slight movement of the control tube is observed, or a step–up in effort to turn the screwdriver is noted. This will place the No. 1L injector rack in the *full–fuel* position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N·m).

The above steps should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

5. To be sure of proper adjustment, hold the stop lever in the *run* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack (Fig. 4). Hold the stop lever in the *run* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 5) and when the pressure of the screwdriver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw. The setting is too tight if, when moving the stop lever from the *stop* to the *run* position, the injector rack becomes tight before the governor stop lever reaches the end of its travel. This will result in a step–up in effort required to move the stop lever to the *run* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

6. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.
7. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 4 for the No. 1L control lever.
8. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the 1L and 1R injector rack control levers as outlined in Step 5. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.
9. Manually hold the No. 1L injector rack in the *full–fuel* position, with the lever on the injector control tube, and turn the inner adjusting screw of the No. 2L injector rack control lever down until the No. 2L injector rack moves into the *full–fuel* position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.
10. Recheck the No. 1L injector rack to be sure that it has remained snug on the ball end of the rack control lever

while positioning the No. 2L injector rack. If the rack of the No. 1L injector has become loose, back off the inner adjusting screw slightly on the No. 2L injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the rack of each injector must be snug on the ball end of its respective control lever.

11. Position the No. 3L and No. 4L injector rack control levers as outlined in Steps 9 and 10.

12. Position the No. 2R, 3R and 4R injector rack control levers as outlined for the left cylinder bank in Steps 9 through 11.

13. Use new gaskets and install the valve rocker covers.

Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, the maximum no-load speed may be set as follows:

NOTICE: The maximum no-load speed must not exceed 150 rpm above the full-load speed.

Start the engine and after it reaches normal operating temperature, determine the maximum no-load speed of the engine with an accurate tachometer. Then stop the engine and make the following adjustments, if required.

1. Refer to Fig. 16 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the variable speed spring housing and the spring retainer, located inside of the housing, from the governor housing.

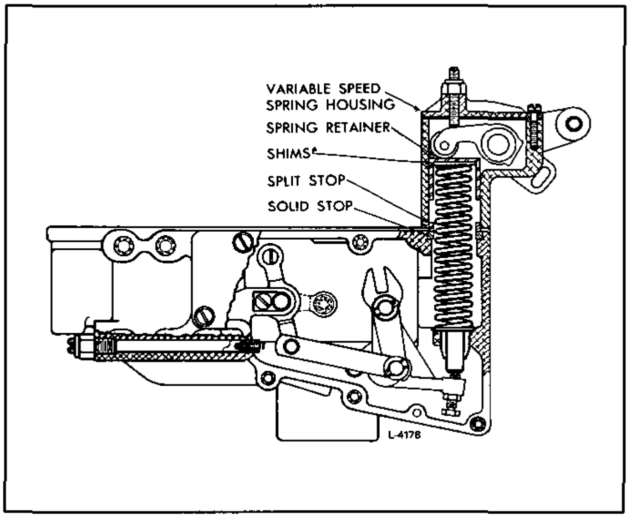


Fig. 13 – Location of Shims and Stops

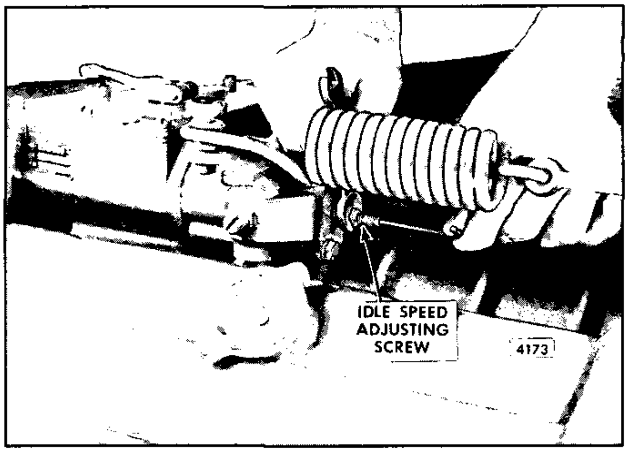


Fig. 14 – Adjusting Idle Speed

3. Refer to Table 1 and determine the stops or shims required for the desired full-load speed. A split stop can only be used with a solid stop (Fig. 13).

4. Install the variable speed spring retainer and housing and tighten the two bolts.

5. Connect the booster spring and the stop lever spring. Start the engine and recheck the maximum no-load speed.

6. If required, add shims to obtain the necessary operating speed. For each .001" in shims added, the operating speed will increase approximately 2 rpm.

If the maximum no-load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no-load speed properly set, adjust the idle speed as follows:

1. Place the stop lever in the *run* position and the speed control lever in the *idle* position.

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the lock nut and turn the idle speed adjusting screw (Fig. 14) in or out until the engine idles at 600 rpm.

4. Hold the idle speed adjusting screw and tighten the lock nut.

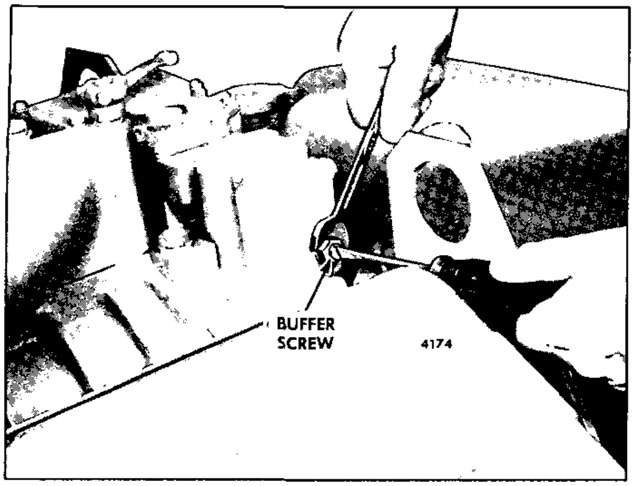


Fig. 15 – Adjusting Buffer Screw

Adjust Buffer Screw

With the engine idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 15) so that it contacts the differential lever as lightly as possible and still eliminates engine roll. *Do not raise the engine idle speed more than 15 rpm with the buffer screw.*
2. Hold the buffer screw and tighten the lock nut.

Adjust Booster Spring

With the engine idle speed set, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

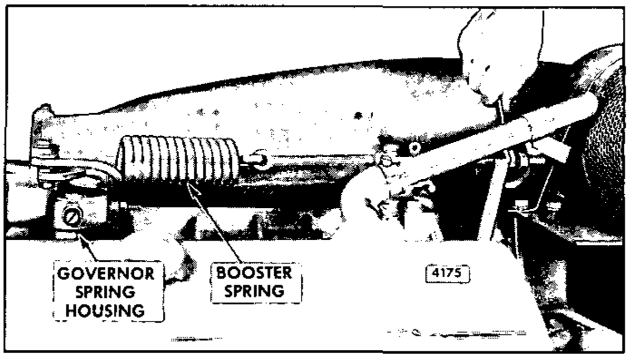


Fig. 16 – Adjusting Booster Spring

2. Refer to Fig. 16 and loosen the booster spring retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the other end of the spring.
3. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the center of the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock nut.
4. Start the engine and move the speed control lever to the maximum speed position and release it. The speed control lever should return to the idle position. If it does not, reduce the tension on the booster spring. If the lever does return to the idle position, continue to increase the spring tension until the point is reached that it will not return to idle. Then reduce the tension until it does return to idle and tighten the lock nut on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.
5. Connect the linkage to the governor levers.

CONSTANT SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and injector rack control levers.

Adjust Governor Gap

1. Stop the engine and disconnect any linkage attached to the speed control lever.
2. Remove the governor cover and lever assembly.
3. Remove the fuel rod from the differential lever and the injector control tube lever.
4. Insert a .006" feeler gage between the spring plunger and the plunger guide as shown in Fig. 1. If required, loosen the lock nut and turn the gap adjusting screw in or out until a slight drag is noted on the feeler gage.
5. Hold the adjusting screw and tighten the lock nut. Check the gap and readjust if necessary.
6. Install the governor cover as follows:
   a. Place the cover on the governor housing, with the pin in the throttle shaft assembly entering the slot in the differential lever.

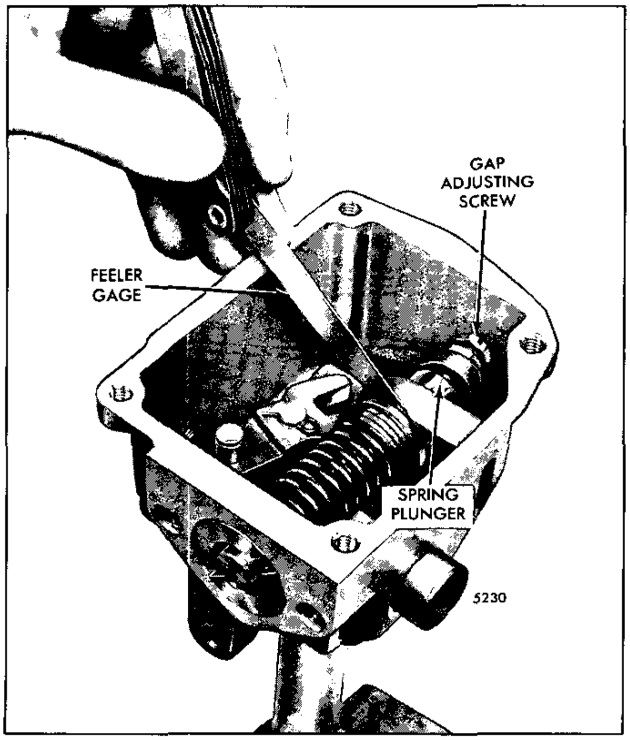


Fig. 1 – Adjusting Governor Gap

   b. Install the four cover screws and lock washers finger tight.
   c. Pull the cover assembly in a direction away from the engine, to take up the slack, and tighten the cover screws. This step is required since no dowels are used to locate the cover on the housing.

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Adjust the No. 1 injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the control lever.
2. Remove the valve rocker cover.
3. Loosen all of the inner and outer injector rack control lever adjusting screws. Be sure all of the control levers are free on the injector control tube.
4. Move the control lever to the maximum speed position. Turn the inner adjusting screw down until a step–up in effort is noted. This will place the No. 1 injector rack in the *full–fuel* position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws. The recommended torque of the adjusting screws is 24–36 **lb–in.**

   NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube.

5. To be sure the control lever is properly adjusted, hold the speed control lever in the maximum speed position and press down on the injector rack with a screw driver or finger tip and note the "rotating" movement of the injector control rack (Fig. 2). Hold the speed control lever in the maximum speed position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 3) and when the pressure of the screw driver is released, the control rack should "spring" back upward.
6. If no movement is observed, back off the inner adjusting screw approximately 1/8 of a turn and tighten the outer adjusting screw. If the movement exceeds that specified, back off the outer adjusting screw approximately 1/8 of a turn and tighten the

inner adjusting screw. When the setting is correct, the injector rack will be snug on the pin of the rack control lever and still maintain the movement specified in Step 5.

Performing Steps 4, 5 and 6 will result in placing the governor linkage and control tube assembly in the same positions that they will attain while the engine is running at full load. These positions are:

a. The governor speed control lever is at the maximum speed position.

b. The governor gap is closed.

c. The governor spring plunger is on its seat in the governor control housing.

d. The injector fuel control racks are in the maximum speed position.

7. Remove the clevis pin between the fuel rod and the injector control tube lever.

8. Manually hold the No. 1 injector in the maximum fuel position and turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into the maximum speed position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

9. Recheck the No. 1 injector fuel rack to be sure that it has remained snug on the pin of the rack control lever while adjusting the No. 2 injector. If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the pins of their respective rack control levers.

10. Position the remaining control rack levers as outlined in Steps 8 and 9.

11. Insert the clevis pin between the fuel rod and the injector control tube lever.

12. Install the valve rocker cover.

Adjust Maximum No–Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine name plate, the maximum no–load speed may be set as follows:

1. Start and warm up the engine.

2. Run the engine at no–load and observe the engine speed. Be sure the speed control lever is in the run position. *There must be no load on the engine during the maximum no–load speed adjustment.*

3. Observe the engine speed and set it, if necessary, to the recommended speed with shims placed between the operating speed spring and the spring plunger.

Since the engine performance and efficiency will be governed, to a large extent, by the accuracy with which the tune–up adjustments are made, the service technician should always perform these operations carefully.

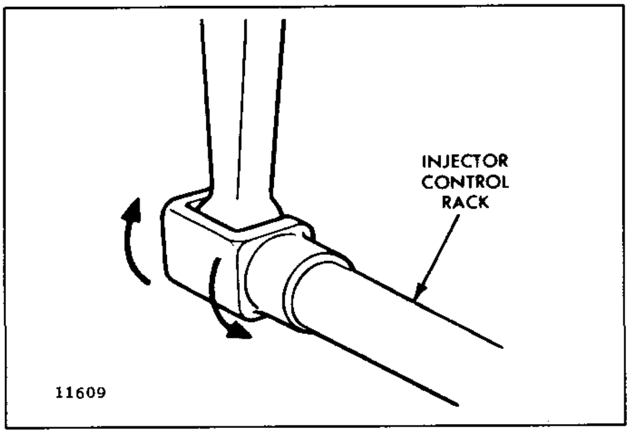


Fig. 2 – Checking Rotating Movement of Injector Control Rack

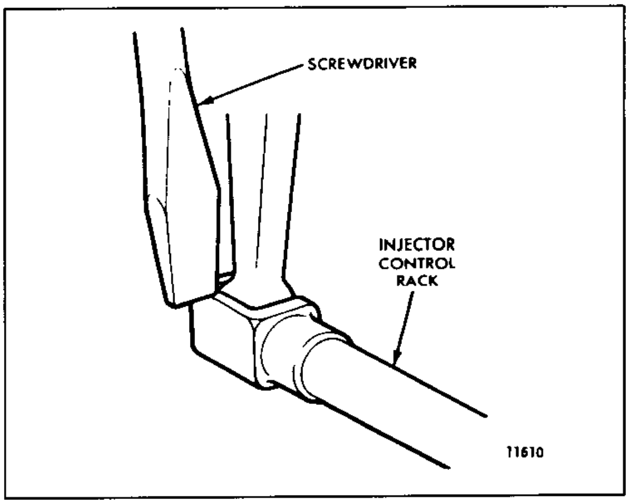


Fig. 3 – Checking Injector Control Rack "Spring"

HYDRAULIC GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN–LINE ENGINE

The hydraulic governor is mounted on the 2–53, 3–53 and 4–53 engines (Fig. 1). The terminal lever return spring and the fuel rod are attached to an external terminal shaft lever. The maximum fuel position of the governor load limit is determined by the internal governor terminal lever striking against a boss that projects from the governor cover.

Adjust the hydraulic governor after adjusting the exhaust valve clearance and timing the fuel injectors.

NOTICE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact.

After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Adjust Fuel Rod And Injector Rack Control Levers

1. Adjust the inner and outer adjusting screws (Fig. 2) on the rear injector rack control lever until both the screws are equal in height and tight on the control tube.

   Some engines use spring–loaded control tube assemblies which have a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. Adjust the single screw and locknut on each injector rack control lever to a central or middle position.

   Check the clearance between the fuel rod and the cylinder head bolt or the cylinder head casting (below the bolt) for at least 1/16" clearance when the injector rack is in the *full–fuel* position and the rack adjusting screws are tight. If the fuel rod contacts the bolt or the cylinder head casting, readjust the screws to obtain the 1/16" clearance.

   NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque on the adjusting screws is 24–36 **lb–in** (3–4 N·m).

2. Remove the governor terminal lever return spring.

3. Remove the fuel rod end bearing or ball joint from the terminal shaft lever and the terminal lever from the terminal shaft.

4. Place the terminal lever on the terminal shaft so that the hole for attaching the fuel rod end bearing or ball joint is in line vertically above the terminal lever shaft at one half the arc of travel. Do not tighten the clamping bolt.

5. Hold both the injector rack control tube and the terminal lever in the *full–fuel* position and adjust the length of the fuel rod until the end bearing or ball joint will slide freely into the hole of the terminal lever (Fig. 3). Tighten the locknut, to retain the ball joint or end bearing, and the terminal lever clamping bolt securely.

   It will be necessary to slide the terminal lever partially off of the shaft to attach the fuel rod end bearing or ball joint to the terminal lever.

   On former governors that do not have the load limit screw in the cover, hold the terminal lever in the *full–fuel* position and loosen the inner adjusting screw 1/8 of a turn and tighten the outer adjusting screw 1/8 of a turn to retain the adjustment. This is done to prevent the governor from bottoming the injector racks.

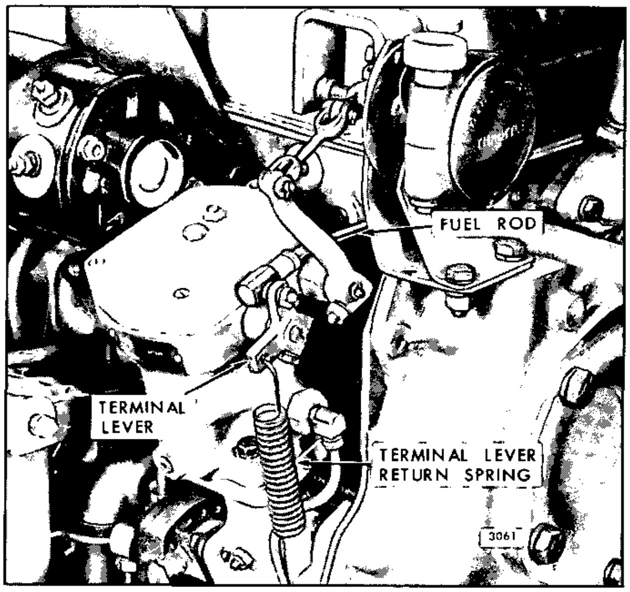


Fig. 1 – Hydraulic Governor Mounting

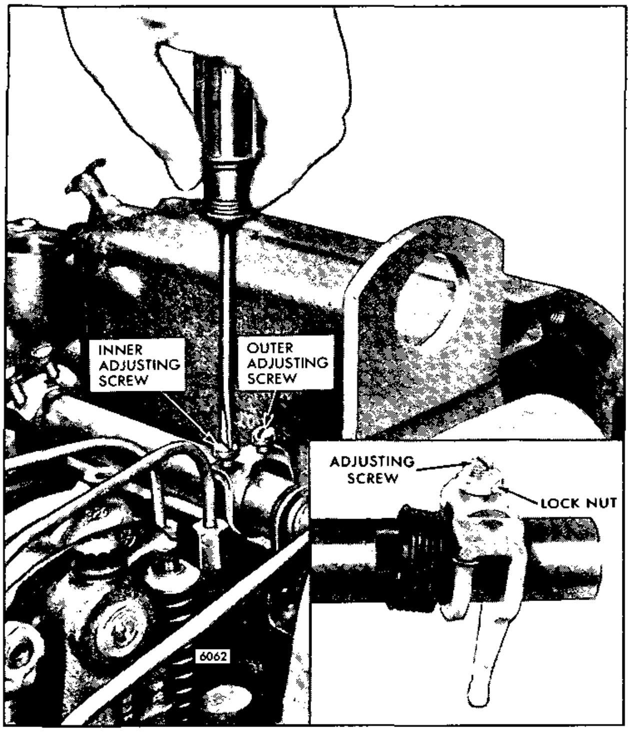


Fig. 2 – Adjusting Height of Rack Control Lever Adjusting Screws

6. Remove the clevis pin between the fuel rod and the injector control tube lever.

   NOTICE: Cover the cylinder head oil drain–back hole, located under the control lever, when removing the fuel rod clevis pin to prevent loss of the pin and possible damage to the engine.

7. Manually hold the rear injector in the *full–fuel* position with the lever on the injector control tube. Turn the adjusting screw of the rear injector rack control lever until the injector rack moves into the *full–fuel* position.

On a *Two Screw Assembly,* turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

Then, alternately tighten both the inner and outer adjusting screws.

On a *One Screw and Locknut Assembly,* turn the adjusting screw until a slight roll–up on the injector rack clevis is observed or an increase in effort to turn the screwdriver is noted, then securely lock the adjusting screw locknut.

8. Recheck the rear injector fuel rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off slightly on the adjusting screw on the adjacent injector rack control lever. When the settings are correct, the racks of all injectors must be snug on the ball end of their respective rack control levers.

9. Position the remaining rack control levers as outlined in Steps 7 and 8.

10. Insert the clevis pin between the fuel rod and the injector control tube lever.

11. On current governors, that have the load limit screw in the governor cover (refer to Section 2.8.1), hold the terminal lever in the *full–fuel* position and adjust the load limit screw until it just contacts the terminal lever.

Then, advance the load limit screw enough to cause the injector racks to just become loose on the control tube levers. This will allow the terminal lever to reach full travel before the injector racks bottom.

12. Install the terminal lever return spring.

Adjust Speed Droop

The purpose of adjusting the speed droop is to establish a definite engine speed at no load with a given speed at rated full load.

The governor droop is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs, the speed droop should be readjusted.

The best method of determining the engine speed is by the use of an accurate hand tachometer.

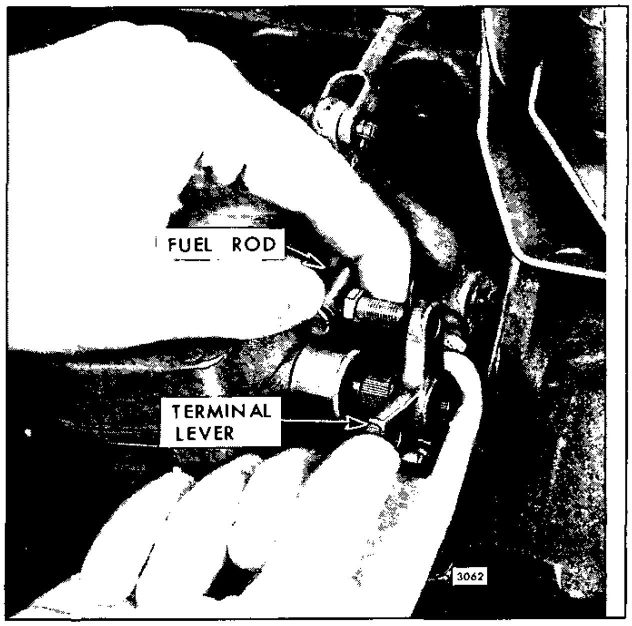


Fig. 3 – Adjusting Length of Fuel Rod

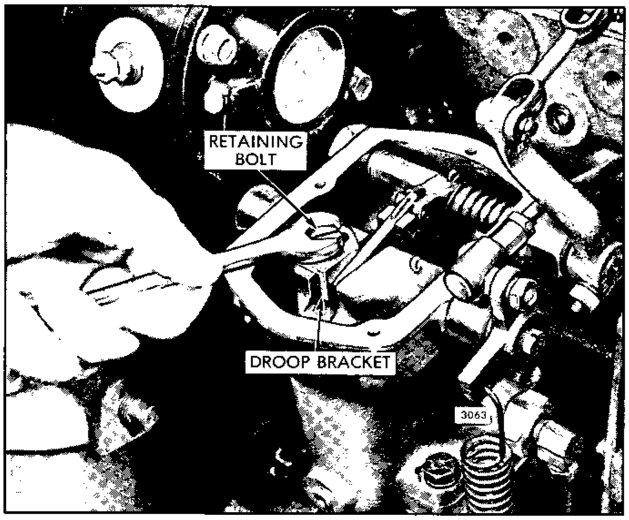


Fig. 4 – Adjusting Droop Bracket

If a full–rated load on the unit can be established and the fuel rod, injector rack control levers and load limit have been adjusted, the speed droop may be adjusted as follows:

1. Start the engine and run it at approximately one–half the rated no–load speed until the lubricating oil temperature stabilizer.

   When the engine lubricating oil is cold, the governor regulation may be erratic. The regulation should become increasingly stable as the temperature of the lubricating oil increases.

2. Stop the engine and remove the governor cover. Discard the gasket.

3. Loosen the locknut and back off the maximum speed adjusting screw approximately 5/8" (Fig. 5).

4. Refer to Fig. 4 and loosen the droop adjusting bolt. Move the droop bracket so that the bolt is midway between the ends of the slot in the bracket. Tighten the bolt.

5. With the throttle in the *run* position, adjust the engine speed until the engine is operating at 3% to 5% above the recommended full–load speed.

6. Apply the full–rated load on the engine and readjust the engine speed to the correct full–load speed.

Full Load	No-Load
50 cycles 1000 rpm	52.5 cycles 1050 rpm
60 cycles 1200 rpm	62.5 cycles 1250 rpm
50 cycles 1500 rpm	52.5 cycles 1575 rpm
60 cycles 1800 rpm	62.5 cycles 1875 rpm

TABLE 1

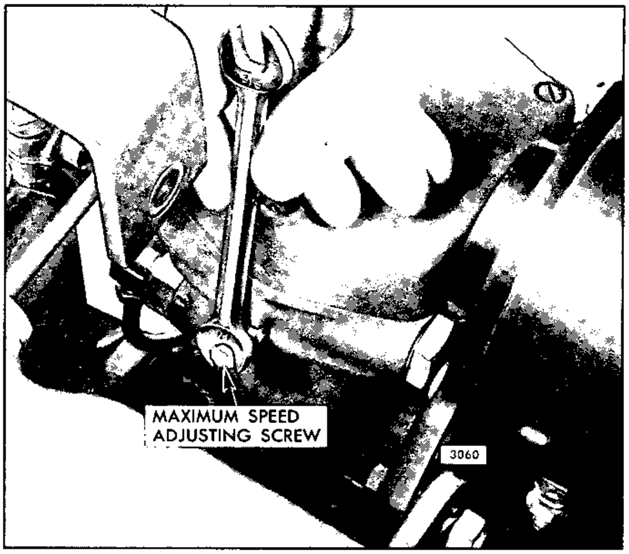


Fig. 5 – Adjusting Maximum Engine Speed

7. Remove the rated load and note the engine speed after the speed stabilizes under no load. If the speed droop is correct, the engine speed will be approximately 3% to 5% higher than the full–load speed.

If the speed droop is too high, stop the engine and again loosen the droop bracket retaining bolt and move the droop adjusting bracket *in* toward the engine. Tighten the bolt. To increase the speed droop, move the droop adjusting bracket *out*, away from the engine.

The speed droop in governors which control engines driving generators in parallel must be identical, otherwise the electrical load will not be equally divided.

Adjust the speed droop bracket in each engine governor to obtain the desired variation between the engine no–load and full–load speeds (Table 1).

The recommended speed droop of generator sets operating in parallel is 50 rpm (2–1/2 cycles) for units operating at 1000 and 1200 rpm and 75 rpm (2–1/2 cycles) for units operating at 1500 rpm and 1800 rpm full load. This speed droop recommendation may be varied to suit the individual application.

Adjust Maximum No–Load Speed

With the speed droop properly adjusted, set the maximum no–load speed as follows:

1. Loosen the maximum speed adjusting screw locknut and back out the maximum speed adjusting screw 3 turns.

2. With the engine operating at no load, adjust the engine speed until the engine is operating at approximately 8% higher than the rated full–load speed.

3. Turn the maximum speed adjusting screw in lightly until contact is felt with the linkage in the governor (Fig. 5).
4. Hold the maximum speed adjusting screw and tighten the locknut.
5. Use a new gasket and install the governor cover.

SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

ENGINE LOAD LIMIT DEVICE

Engines with mechanical governors may be equipped with a load limit device to reduce the maximum horsepower (Fig. 1)

This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a load limit lever clamped to the injector control tube.

The load limit device is located between the No. 2 and No. 3 cylinders of a 3–53 or 4–53 engine or between the No. 1 and No. 2 cylinders of *each* cylinder head on a V–type engine. However, when valve rocker covers with a breather are used, the load limit device is installed between the No. 1 and No. 2 cylinders on In–line engines and between the No. 2 and No. 3 cylinders on V–type engines to avoid interference with the rocker cover baffles.

When properly adjusted for the maximum horsepower desired, this device limits the travel of the injector control racks and thereby the fuel ouput of the injectors.

Adjustment

After the engine tune–up is completed, make sure the load limit device is properly installed (Fig. 1). Make sure the counterbores in the adjusting screw plate are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 50–55 lb–ft (68–75 N·m) torque. Then adjust the load limit device, on each cylinder head, as follows:

1. Loosen the load limit screw locknut and remove the screw.
2. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.
3. With the screw out of the plate, adjust the load limit screw locknut so the bottom of the locknut is 7/8" from the bottom of the load limit screw for the initial setting (Fig. 1).
4. Loosen the load limit lever clamp bolts so that the lever is free to turn on the injector rack control tube.
5. Thread the load limit screw into the adjusting screw plate until the locknut *bottoms* against the top of the plate.
6. Hold the injector rack control tube in the *full–fuel* position and place the load limit lever against the bottom of the load limit screw. Then, tighten the load limit lever clamp bolts.
7. Check to ensure that the injector racks will just go into the *full–fuel* position – readjust the load limit lever, if necessary.
8. Hold the load limit screw to keep it from turning, then *set* the locknut until the distance between the bottom of the locknut and the top of the adjusting screw plate corresponds to the dimension (or number of turns) stamped on the plate. Each full turn of the screw equals .042", or .007" for each flat on the hexagon head.

   If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand and note the number of turns required to obtain the desired horsepower. Then, stamp the plate accordingly.
9. Thread the load limit screw into the plate until the locknut *bottoms* against the top of the plate. Be sure the nut turns with the screw.
10. Hold the load limit screw to keep it from turning, then tighten the lock nut to secure the setting.

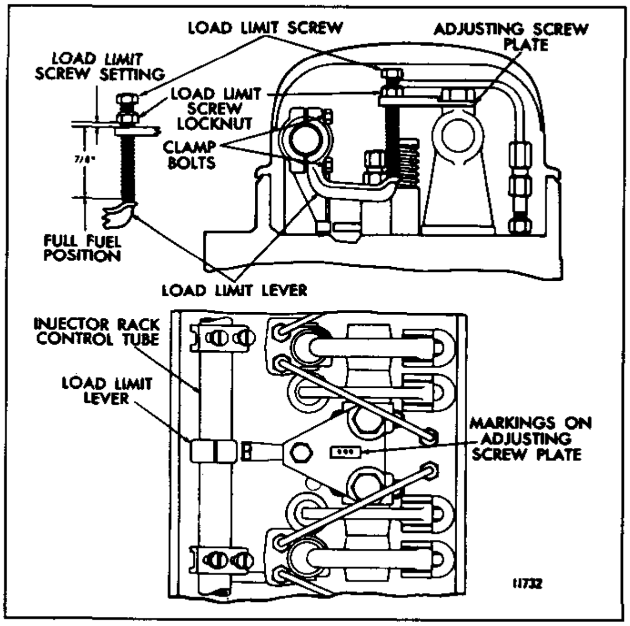


Fig. 1 – Engine Load Limit Device

THROTTLE DELAY MECHANISM

The *throttle* delay *mechanism* is used to retard *full-fuel* injection when the engine is accelerated. This reduces exhaust smoke and also helps to improve fuel economy.

The throttle delay mechanism (Fig. 2) is installed between the No. 1 and No. 2 cylinders on 3–53 engines, between the No. 2 and No. 3 cylinders on 4–53 engines, or between the No. 1 and No. 2 cylinders on the right-bank cylinder head of V-type engines. It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link, orifice plug, ball check valve and U-bolt.

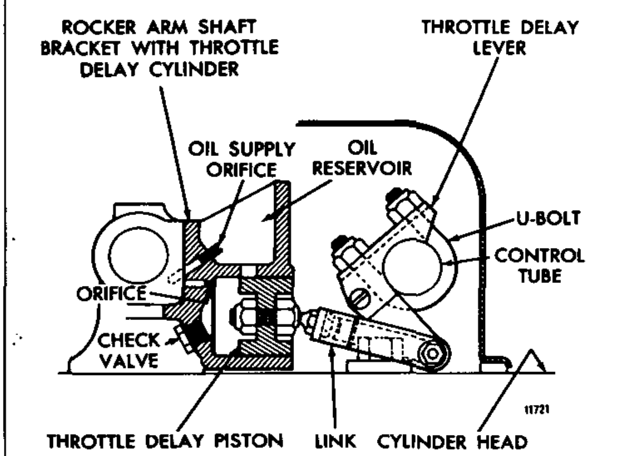


Fig. 2 – Throttle Delay Mechanism

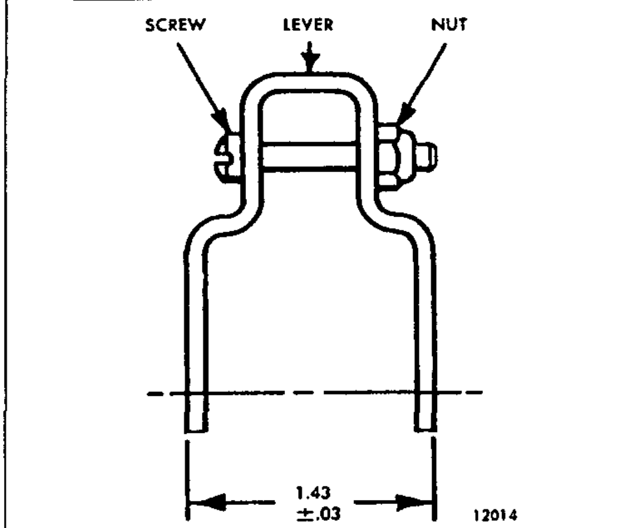


Fig. 3 – Current Throttle Delay Lever Assembly

Effective with turbocharged engines built January, 1980 10–32 x 1 1/8″ screws and 10–32 locknuts are used in the lever assembly rather than 8–32 screws and locknuts. Also, 10–32 x 3/4″ screws and 10–32 locknuts are used at each leg of the lever assembly, rather than 8–32 screws and nuts. The screw holes in the lever were enlarged to accommodate the 10–32 screws (Fig. 3).

DO NOT use a 10–32 locknut on an 8–32 screw. An 8–32 nut must be used with an 8–32 screw and a 10–32 nut used with a 10–32 screw.

Effective February, 1975, a new throttle delay lever is used on the 4 and 6V–53 engines (Fig. 3). The lever assembly consists of a throttle delay lever (not serviced separately), an 8–32 x 1 1/8″ screw and a stop nut.

> **NOTICE:** Install the throttle delay lever assembly on the injector control tube with the legs inward (Fig. 2). A backward installation (legs outward) can result in a binding condition between the lever and the valve cover and possible loss of injector fuel control. Adjust the lever to obtain a leg width of 1.43″ ± .03″ (Fig. 3) to prevent binding.

Prior to May, 1973, the throttle delay lever assembly was the same as the current lever assembly, except that the lever was serviced separately and no adjustment dimension was specified.

Effective May, 1973 and until February, 1975, the throttle delay lever was used with an 8–32 x 1.20″ long spacer and an 8–32 x 2 1/2″ screw instead of the two shorter 8–32 x 3/4″ screws at each leg of the lever. Also, the 1 1/8″ long adjusting screw was eliminated. The single 2 1/2″ long screw and spacer was discontinued because it was found that *the spacer could hit the cylinder head bolt, preventing the* fuel injectors from reaching full rack position.

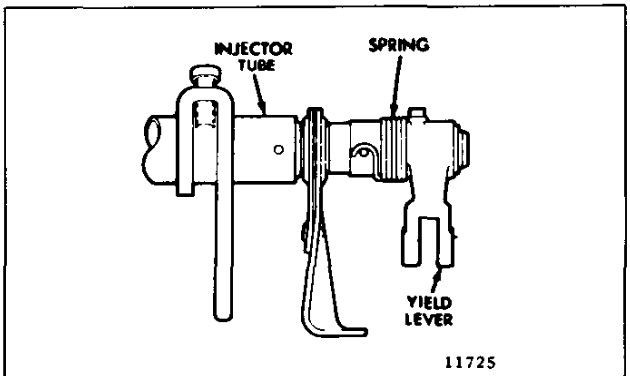


Fig. 4 – Throttle Delay Yield Lever (In-line Engine)

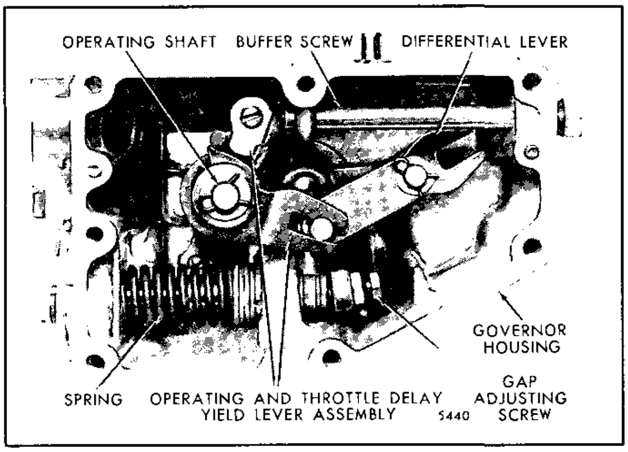


Fig. 5 – Throttle Delay Yield Lever (6V–53 Engine)

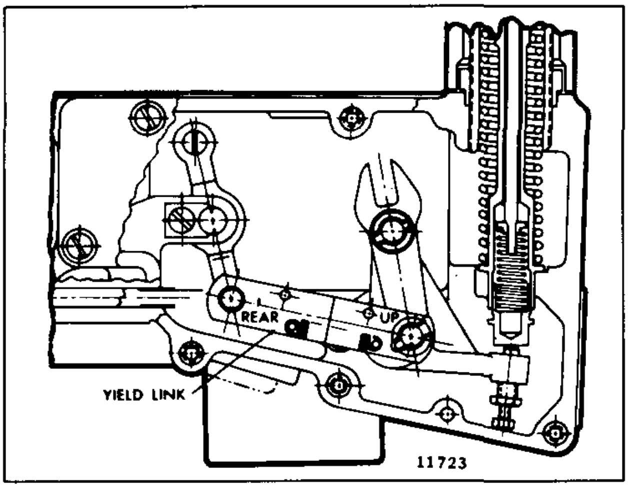


Fig. 6 – Throttle Delay Yield Link (8V–53 Engine)

Former engines can be updated by replacing the 1.20" long spacer and 2 1/2" screw with the shorter 3/4" screws and nuts at each leg of the throttle delay lever. Add the 1 1/8" long screw and nut to the lever.

Adjust the current throttle delay lever assembly (Fig. 3) by loosening or tightening the screw and nut in the lever to obtain a width of 1.43" $\pm$ .03" between the lever legs.

NOTICE: This dimension is required to prevent the lever from binding with the link.

A yield lever and spring assembly replaces the standard lever and pin assembly on the rear end of the injector control tube on In–line engines (Fig. 4). A yield lever replaces the standard operating lever in the governor of the 6V–53 engine (Fig. 5) and a yield link replaces the standard operating lever link in the 8V–53 governor (Fig. 6).

Operation

Oil is supplied to a reservoir above the throttle delay cylinder through an orifice plug in the drilled oil passage in the rocker arm shaft bracket (Fig. 2). As the injector racks are moved toward the *no–fuel* position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the *full–fuel* position is momentarily retarded while the piston expels the oil from the cylinder through an orifice. To permit full accelerator travel, regardless of the retarded injector rack position, a spring–loaded yield lever or link assembly replaces the standard operating lever connecting link to the governor.

Inspection

To inspect the check valve, fill the throttle delay cylinder with diesel fuel oil and watch for check valve leakage while moving the engine throttle from the idle position to the *full–fuel* position. If more than a drop of leakage occurs, replace the check valve.

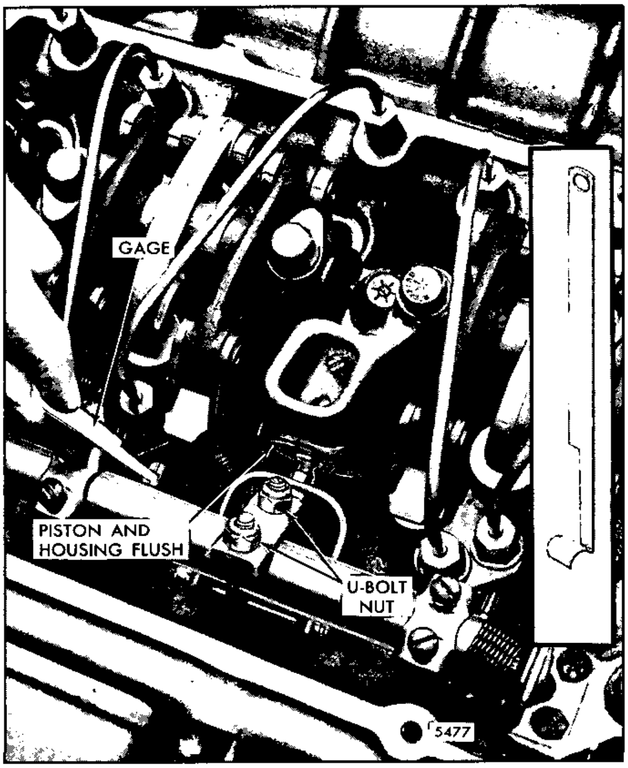


Fig. 7 – Adjusting Throttle Delay Cylinder

Adjustment

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U–bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. Refer to Fig. 7 and insert gage J 23190 (.454" setting) between the injector body and the shoulder on the injector rack. Then exert a light pressure on the injector control tube in the direction of full fuel.
2. Align the throttle delay piston so it is flush with the edge of the throttle delay cylinder.
3. Tighten the U–bolt on the injector control tube and remove the gage.
4. Move the injector rack from the *no–fuel* to the *full–fuel* position to make sure it does not bind.

Refer to *Engine Tune–Up* in Section 15.1 for maintenance.

ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor) or the right angle clip (limiting speed governor) to the stop lever (Figs. 8 and 9). Align and clamp the lever to the shutdown shaft in such a way that, at its mid–travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" travel which is more than adequate to move the injector control racks from the *full–fuel* to the complete *no–fuel* position and shutdown will occur prior to attaining complete travel.
2. With the stop lever in the *run* position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed. The oversize hole in the eye or clip will thereby permit the solenoid to start closing the air gap, with a resultant build–up of pull–in force prior to initiating stop lever movement.
3. The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32" minimum. The locknut can be either on top of or below the stop lever.
4. Move the lever to the *stop* position and observe the plunger for any possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger motion.

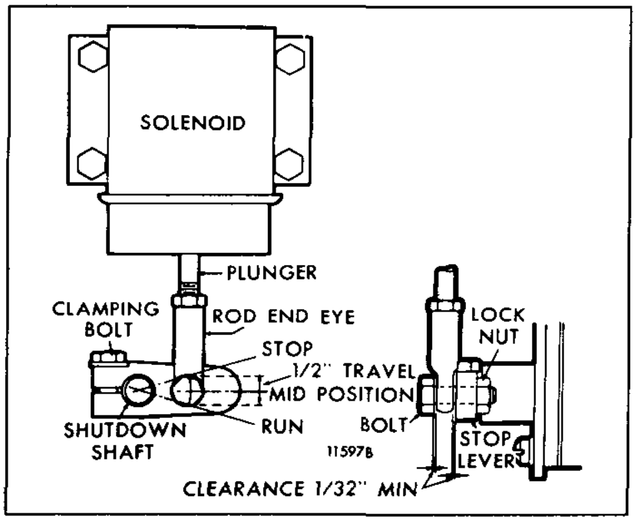


Fig. 8 – Typical Variable Speed Governor Lever Position

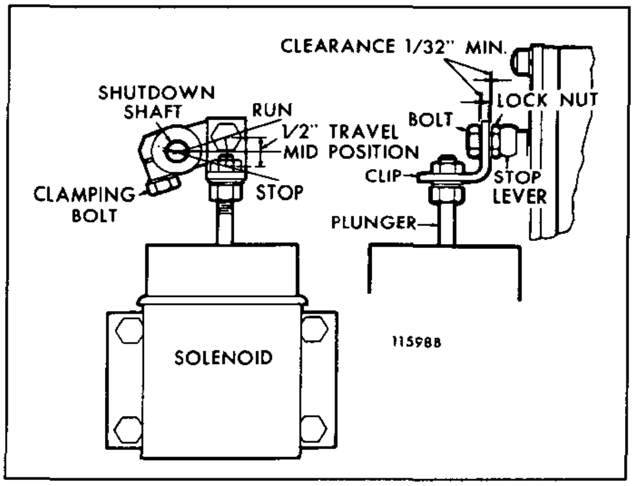


Fig. 9 – Typical Limiting Speed Governor Lever Position

FUEL MODULATOR

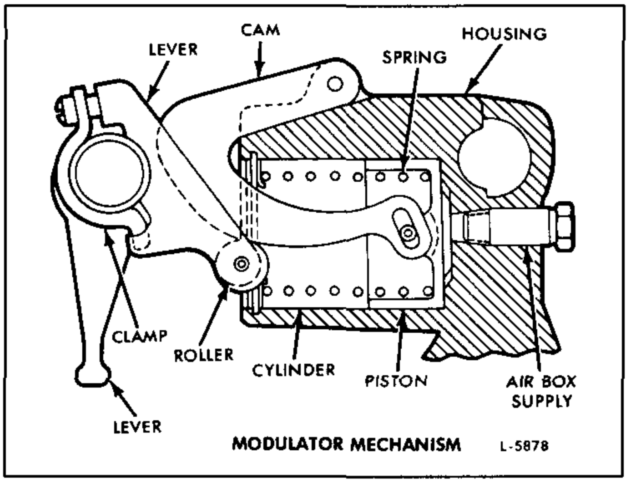


Fig. 10 – Typical Fuel Modulator Assembly

The fuel modulator, used on turbocharged engines, maintains the proper fuel to air ratio in the lower speed ranges where the mechanical governor would normally act to provide maximum injector output. It operates in such a manner that, although the engine throttle may be moved into the full–speed position, the injector racks cannot advance to the *full–fuel* position until the turbine speed is sufficient to provide proper combustion.

The fuel modulator will reduce exhaust smoke and also will help to improve fuel economy. The modulator mechanism is installed between the No. 1 and No. 2 cylinders.

A fuel modulator consists of a cast housing containing a cylinder, piston, cam and calibrated spring mounted on the cylinder head (Table 1). A lever and roller which controls the injector rack is connected to the injector control tube. Tubes run from the air box to the housing to supply pressure to actuate the piston.

FUEL MODULATING SPRING IDENTIFICATION

COLOR CODE	LOAD	RATE
Pink Stripe	5.61 ± 1.5 Lbs. @ 1.125 Length	6.00 Lbs. Per Inch.
Green Stripe	26.9 ± 1.34 Lbs. @ .65 Length	18.25 Lbs. Per Inch.
None	28.25 ± 1.4 Lbs. @ .65 Length	16.25 Lbs. Per Inch.

TABLE 1

The modulator tells the fuel system how much fuel the engine can efficiently use based on air box pressure. Increased air box pressure forces the piston and cam out of the cylinder bore allowing the rack to move toward full fuel.

The spring is calibrated to the individual engine model air box pressure characteristics.

Whenever the fuel injector rack control levers are adjusted, the fuel (air box) modulator lever and roller assembly must first be positioned free of cam contact. This is done by loosening the clamp screw.

Inspection

At major repair or overhaul, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear. Also, inspect the operating surface, the lever roller, the roller pins at the cam pivot and the cam attachment to the piston.

The piston outer diamter must not be less than 1.6555" and the cylinder bore inner diameter must not be more than 1.6605".

Adjust Fuel Modulator

After completing the injector rack control lever and governor adjustment, adjust the fuel modulator, as follows:

1. With the engine stopped, insert the proper gage between the injector body and the shoulder on the injector rack of the No. 2 injector which is adjacent to the modulator (Table 2).
2. Position the governor speed control lever in the maximum speed position and the governor run stop lever in the *run* position.
3. Rotate the air box modulator lever assembly and clamp on the injector control tube until the lever roller contacts the modulator cam with sufficient force to take up the pin clearance (Fig. 10).
4. Check to make sure only the roller contacts the cam and not the lever stamping. Tighten the lever and clamp screw. After tightening, check to make sure that the gage is still in contact with the injector body and the shoulder on the injector rack of the No. 2 injector.
5. Remove the gage from between the injector body and the shoulder on the injector rack.

TOOL NO.	DIM.	USAGE
J35586	.200	53T with crosshead pistons improved cold weather starting
J26646	.290	3, 4-53T Off-Highway, Industrial (except 4-53T with N65 injectors)
J28779	.365	4-53T Truck with 5A55 injectors and 4-53T Off-Highway Industrial with N65 injectors
J28778	.365	4-53T Truck with 5A60 injectors (except California)
J9509C	.404	4-53T Truck with 5A60 injectors (California only)
J9509C	.404	4-53T Truck with N65 injectors
J9509C	.404	6V-53T Truck, Off-Highway, Industrial
J28779	.365	6V-53T Marine

TABLE 2

SECTION 15

PREVENTIVE MAINTENANCE – TROUBLESHOOTING – STORAGE

CONTENTS

LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the Charts are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13.1.

EMISSION CONTROL MAINTENANCE
SERVICE CHART
(VEHICLE ENGINES)

DAILY										
1. — Lubricating Oil	Ⓘ									
2. — Fuel Tank	Ⓘ									
3. — Fuel Lines and Flexible Hoses	Ⓘ									
4. — Cooling System	Ⓘ									
5. — Turbocharger	Ⓘ									
3000 MILE INTERVALS										
6. — Battery	Ⓘ									
7. — Tachometer Drive	Ⓘ									
4000-6000 MILE INTERVALS										
8. — Air Cleaner (oil bath)	Ⓘ									
9. — Drive Belts	Ⓘ									
10. — Air Compressor	Ⓘ									
11. — Throttle Control	Ⓘ									
15,000 MILE INTERVALS										
(2.) — Fuel Tank	Ⓘ									
(8.) — Air Cleaner (oil bath)	Ⓘ									
25,000 MILE INTERVALS										
12. — Lubricating Oil Filter	Ⓡ									
6 MONTHS OR — **MONTHS**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**
10,000 MILE INTERVALS — **MILES (1000)**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
13. — Fuel Filter	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
14. — Coolant Filter and Water Pump	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
15. — Starting Motor	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
(2.) — Fuel Tank		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(4.) — *Cooling System (hoses)*		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(10.) — Air Compressor		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
16. — Air System		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
17. — Exhaust System		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
18. — Air Box Drain Tube			Ⓘ			Ⓘ			Ⓘ	
19. — Emergency Shutdown		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
20. — Engine (steam clean)		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
21. — Radiator		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
22. — Shutter Operation		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
23. — Oil Pressure		Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
24. — Governor					Ⓘ					Ⓘ
25. — *Fuel Injector & Valve Clearance*					Ⓘ					Ⓘ
26. — Throttle Delay					Ⓘ					Ⓘ
27. — Generator or Alternator*										
28. — Engine & Transmission Mounts						Ⓘ				
29. — Crankcase Pressure						Ⓘ				
30. — Air Box Check Valves										Ⓘ
(1.) — Lubricating Oil*										
31. — Fan Hub*										

ANNUALLY	
(3.) — Fuel Lines and Flexible Hoses	Ⓘ
(4.) — Cooling System	Ⓘ
(8.) — Air Cleaners	Ⓘ
32. — Thermostats & Seals	Ⓘ
33. — Blower Screen	Ⓘ
34. — Crankcase Breather	Ⓘ
35. — Fan (*thermo-modulated*)	Ⓘ
AS REQUIRED	
36. — Engine Tune-Up	

Ⓘ = INSPECT, CORRECT OR REPLACE (IF NECESSARY)

Ⓡ = REPLACE

*** = SEE ITEM**

INDUSTRIAL OFF HIGHWAY AND MARINE#	TIME INTERVALS										
HRS.		8	50	100	150	200	300	500	700	1,000	2,000
MILES	DLY.	240	1,500	3,000	4,500	6,000	9,000	15,000	20,000	30,000	60,000
1. — Lubricating Oil	x				x						
2. — Fuel Tank	x							x	x		
3. — Fuel Lines/Flexible Hoses	x							x		x	
4. — Cooling System*	x								x	x	
5. — Turbocharger	x										
6. — Battery				x							
7. — Tachometer Drive				x							
8. — Air Cleaners		x					x				
9. — Drive Belts		x				x					
10. — Air Compressor						x			x		
11. — Throttle and Clutch Controls						x					
12. — Lubricating Oil Filter*								x		x	
13. — Fuel Strainer and Filter*							x				
14. — Coolant Filter/Water Pump*								x			
15. — Starting Motor*											
16. — Air System									x		
17. — Exhaust System									x		
18. — Air Box Drain Tube										x	
19. — Emergency Shutdown									x		
21. — Radiator									x		
22. — Shutter Operation									x		
23. — Oil Pressure									x		
24. — Overspeed Governor								x			
26. — Throttle Delay*											
27. — Alternator*											
28. — Engine/Transmission Mounts											x
29. — Crankcase Pressure											x
30. — Air Box Check Valves*											
31. — Fan Hub*									x		
32. — Thermostats and Seals									x		
33. — Blower Screen										x	
34. — Crankcase Breather										x	
36. — Engine Tune-Up*											
37. — Heat Exchanger Electrodes*											
38. — Raw Water Pump*	x										
39. — Power Generator*											
40. — Power Take-Off*											
41. — Marine Gear*	x										
42. — Torqmatic Converter*											
43. — Hydrostarter System*											
44. — Blower Bypass Valve*											

* See Item
\# Marine Engine Time Intervals May Differ. See Item.

Item 1 – Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty (20) minutes to allow the oil to drain back to the oil pan. Add the proper grade oil, as required, to maintain the correct level on the dipstick (refer to Section 13.3).

NOTICE: Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

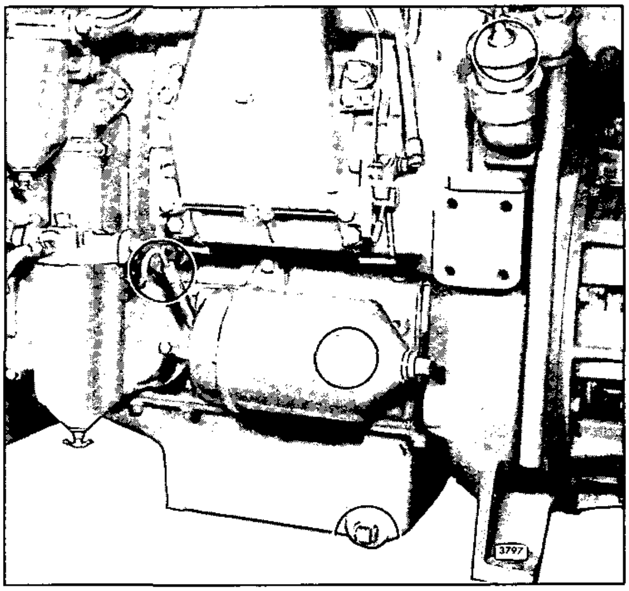
Change the lubricating oil at the intervals shown in the Chart. See Section 13.3 for dráin intervals when using high sulfur fuel (above 0.50 mass percent).

When using high TBN/ash oils, a rule of thumb for oil change intervals is to drain the oil when the TBN drops to one–half of the new oil TBN. *Since lubricant composition varies from brand to brand the time and rate of TBN reduction will vary.* These differences manifested by the various high TBN/ash oils will influence the drain interval.

The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined.

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily. Select the proper grade of oil in accordance with the instructions given in the *Lubrication Specifications* in Section 13.3

ENGINE OIL CHANGE INTERVALS	
Service Application	Max. Engine Oil Change Interval
	Diesel Fuel Sulfur Content 0 to 0.50% by Wt. Max.
City Transit Coaches	6,000 Miles
Pickup Delivery Truck Service (Stop–and–go short distance)	12,000 Miles
Industrial, Agricultural & Marine	150 Hours
Stationary Units: — Full Time — Stand By	500 Hours or 1 Month 150 Hours or 1 Year



Items 1 and 12

Item 2 – Fuel Tanks

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Fuel Specifications* in Section 13.3.

Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water and/or sediment.

Every 12 months or 20,000 miles (700 hours) tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts, as necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10% by volume).

Marine units in storage are particularly susceptible to microbe growth. The microbes live in the fuel–water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non–turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commercially available biocides. There are two basic types on the market:

1. The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.
2. The diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax or equilvalent, treats *the fuel* itself, and therefore, the entire fuel system.

Marine units or any other application going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 – Fuel Lines and Flexible Hoses

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre–start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Make sure that hoses are not resting on or touching shafts, couplings, heated surfaces including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary.

Leaks

Investigate leaks immediately to determine if fittings have loosened or cracked or if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

CAUTION: Personal injury and/or property damage may result from fire due to the leakage of flammable fluids such as fuel or lube oil.

Service Life

A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures, amount of flexing and vibration it is subject to. With this in mind, all hoses should be thoroughly inspected at least every 500 operating hours (1,000 hours for the fire–resistant fuel and lube hoses and heat–insulating turbo/exhaust system blanket) and/or annually. Look for cover damage or indications of damaged, twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

All hoses in or out of machinery should be replaced during major overhaul and/or after a maximum of five years service.

NOTICE: The new hose assemblies do not require automatic replacement after five years service or at major overhaul.

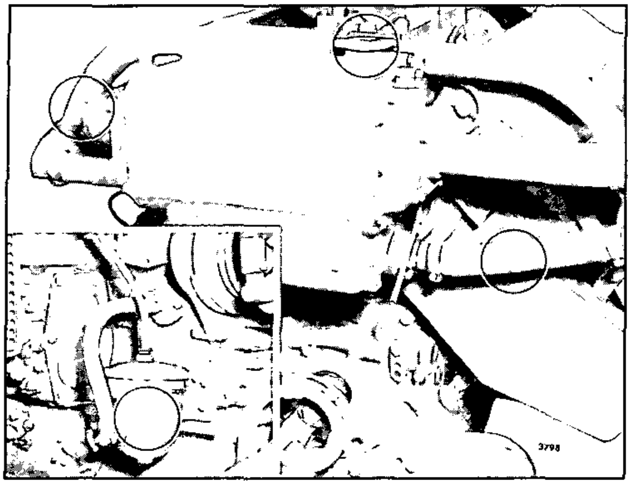
Item 4 – Cooling System

CAUTION: Do not remove the pressure control cap from the radiator or heat exchanger or attempt to drain the coolant until the engine has cooled. Once the engine has cooled, use extreme care when removing the cap. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

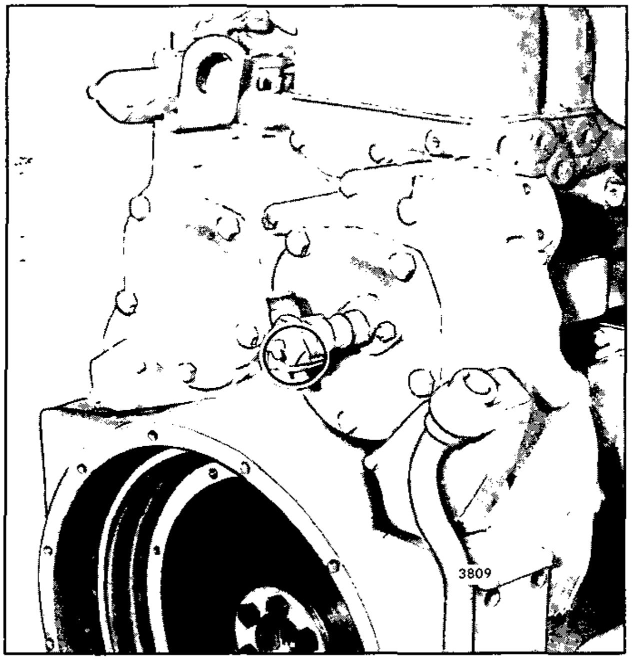
Check the coolant level daily and maintain it near the top of the heat exchanger tank or make sure it covers the radiator tubes. Add coolant, as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

In order to assure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system (15–20 psi or 103–138 kPa) using radiator cap and cooling system tester J 24460–01. Do not exceed 20 psi (138 kPa). Any measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any incipient coolant leaks.



Item 4 and 14



Item 7

• A cooling system properly maintained and protected with supplemental inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. *At this interval the antifreeze must be drained, discarded in* an appropriate manner, and the cooling system throughly cleaned. Inspect all components that make up the cooling system and make necessary repairs at this time. Refill the cooling system with a recommended ethylene glycol-base antifreeze and water solution in the required concentration (see Section 13.3). Add required inhibitors. After filling, run engine until thermostat(s) open and top off to recommended *full* level. Reinstall fill/pressure cap.

Inspect all of the cooling system hoses at least once every 700 hours or 20,000 miles to make sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses, if necessary.

Item 5 – Turbocharger

CAUTION: To eliminate the possibility of personal injury when air inlet piping is removed, do not operate an engine with a turbocharger unless the compressor inlet guard assembly or turbo inlet shield (J 26554-A) is installed.

• Visually inspect the mountings, intake and exhaust ducting and connections for leaks daily. Check the oil inlet and outlet lines for leaks or restrictions to oil flow. Check for unusual noise or vibration and, if excessive, stop the engine and do not operate until the cause is determined.

The exhaust manifold retaining nuts, exhaust flange clamp, and other manifold connections should also be checked for leakage and tightened, if necessary.

Check heat-insulating exhaust system blankets for damage daily. Torn, matted, crushed, oil-soaked, or otherwise damaged insulation blankets *must* be replaced immediately.

Item 6 – Battery

Check the "eye" of maintenance-free batteries for charge. If lead-acid or low maintenance batteries are used, check the specific gravity of the electrolyte in each cell every 100 hours or 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 7 – Tachometer Drive

Lubricate the tachometer drive every 100 hours or 3,000 miles with an all purpose grease at the grease fitting. At temperatures above 30°F (–1°C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 8 – Air Cleaner

Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non-turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Oil Bath

Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours (every 6,000 miles for highway vehicle engines), or less if operating

conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade and viscosity *heavy–duty* oil as used in the engine. The frequency of servicing may be varied to suit local dust conditions. If heavy rain or snow has been encountered, check the air cleaner for an accumulation of water.

Remove and steam clean the air cleaner element and baffle annually.

It is recommended that the body and fixed element in the heavy–duty oil bath type air cleaner be serviced every 500 hours or 15,000 miles or as conditions warrant.

Dry Type

Dry type air cleaner elements (Donaldson, Farr, etc.) used in on–highway applications should be discarded and replaced with new elements after one year of service, after 100,000 miles (Donaldson's recommended mileage interval) or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. No attempt should be made to clean or reuse on–highway elements after these intervals.

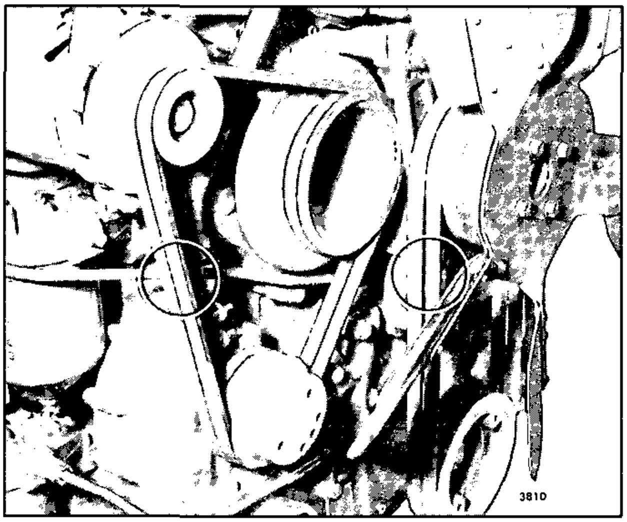
Dry type elements used in off–highway applications should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing off–highway elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

Item 9 – Drive Belts

New standard V–belts will stretch after the first few hours of operation. Run the engine for 15 *seconds* to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, pump drive, battery–charging alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter, check the tension of the drive belts every 200 hours or 6,000 miles and adjust, if necessary. Belts should be neither too tight nor too loose. Belts which are too tight impose excess loads on the crankshaft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. A loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032″ of their specified center distances.

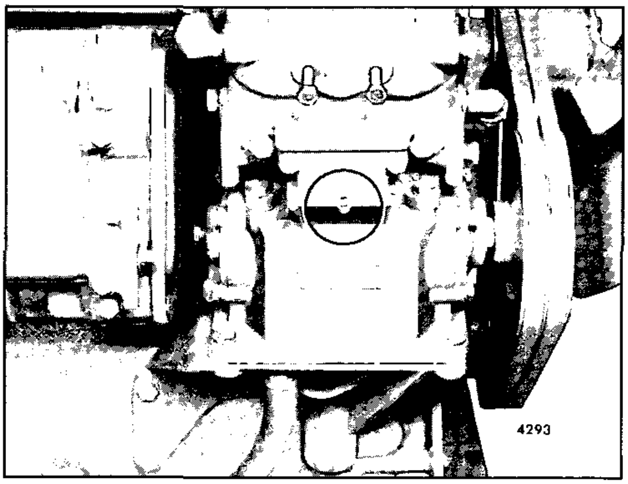
Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2″ to 3/4″. If belt tension gage J 23600–B or equivalent is available, adjust the belt tension, as outlined in the Chart. When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.



Item 9

Model	Fan Drive		Alternator Drive		
	2 or 3 belts	Single belt	Two 3/8″ or 1/2″ belts	One 1/2″ belt	One Wide belt
3, 4-53	40-50	—	40-50	50-70	40-50
6, 8V-53	60-80	80-100	40-50	50-70	40-50
All	For 3-point or triangular drive use a tension of 90-120.				

BELT TENSION CHART (lbs/belt)



Item 10

Item 10 – Air Compressor

Remove and wash all of the polyurethane sponge strainer parts every 5000 miles (150 operating hours). The strainer element should be cleaned or replaced. If the element is cleaned, it should be washed in a commercial solvent or a detergent and water solution. The element should be saturated in clean engine oil, then squeezed dry before replacing it in the strainer. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.

For replacement of the air strainer element, contact the nearest Bendix Westinghouse or Midland–Ross dealer; replace with the polyurethane element, if available.

Every 12 months or 20,000 miles tighten the air compressor mounting bolts. If the air compressor is belt driven, check the belts for proper tension.

Item 11 – Throttle and Clutch Controls

Every 200 hours or 6,000 miles lubricate the throttle control mechanism. Use an all purpose grease (No. 2 grade) at temperatures + 30°F (–1°C) and above. At temperatures below this use a No. 1 grade grease.

Lubricate all other control mechanisms, as required, with engine oil.

Item 12 – Lubricating Oil Filter

Install new oil filter elements and gaskets each time the engine oil is changed. See Section 13.3 for filters and recommended intervals.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, pre–lubricate it as outlined under *Install Turbocharger* in Section 3.5.

If the engine is equipped with a governor oil filter, change the element every 1,000 hours or 30,000 miles.

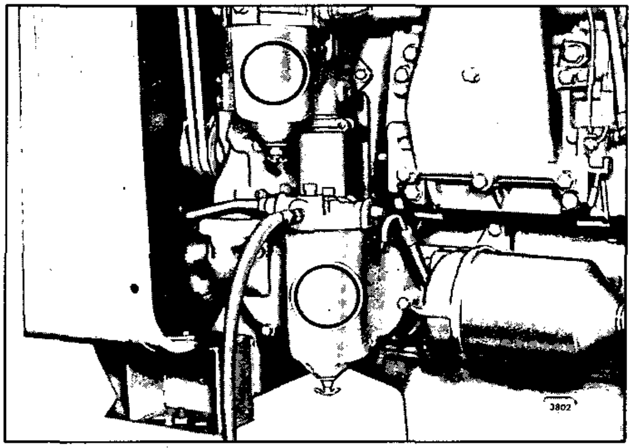
Check for oil leaks after starting the engine.

Item 13 – Fuel Strainer and Filter

Install new elements every 6 months or 10,000 miles (vehicle engines) and 300 hours or 9,000 miles (non–vehicle engines) or when plugging is indicated. See Section 13.3 for filter recommendations.

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). At normal operating speed the fuel pressure is 45–70 psi (310–483 kPa). Change the fuel filter elements whenever the inlet restriction at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and whenever the fuel pressure at the inlet manifold falls below 45 psi (310 kPa).

> **NOTICE:** *To improve starting, have replacement filters filled with fuel and ready to install immediately after used filters are removed. This will prevent possible fuel siphoning, causing fuel system aeration. If the engine fails to start after replacement of the fuel filter element(s), the fuel system will require priming with tool J 5956, or equivalent.*



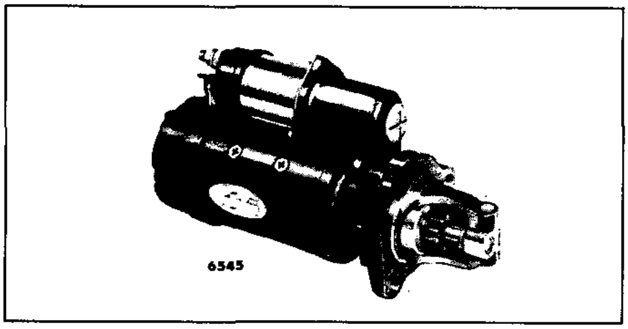
Item 13

Item 14 – Coolant Filter and Water Pump

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 6 months or 10,000 miles (vehicle engines) and 500 hours or 15,000 miles (non–vehicle engines). Select the proper coolant filter element in accordance with the instructions given under *Coolant Specifications* in Section 13.3. Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine and check for leaks.

Inspect the water pump drain hole every 6 months for plugging. If plugged, clean out the drain hole with a tool made from a front crankshaft seal or equivalent.

Replace the water pump seal after it has been in service for 200,000 miles or 6,000 hours.



Item 15

Item 15 – Starting Motor

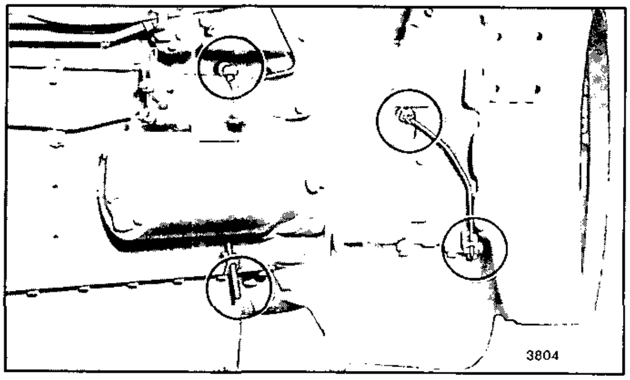
The electrical starting motor is permanently lubricated at the time of manufacture. No further lubrication is required. Follow starter manufacturer's recommendations if disassembly or overhaul is required.

Item 16 – Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.

Item 17 – Exhaust System

Check the exhaust manifold retaining nuts, exhaust flange clamp and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if one is used.



Item 18

Item 18 – Air Box Drain Tube

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours or 30,000 miles. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent.

If the engine is equipped with an air box drain tank, drain the sediment periodically.

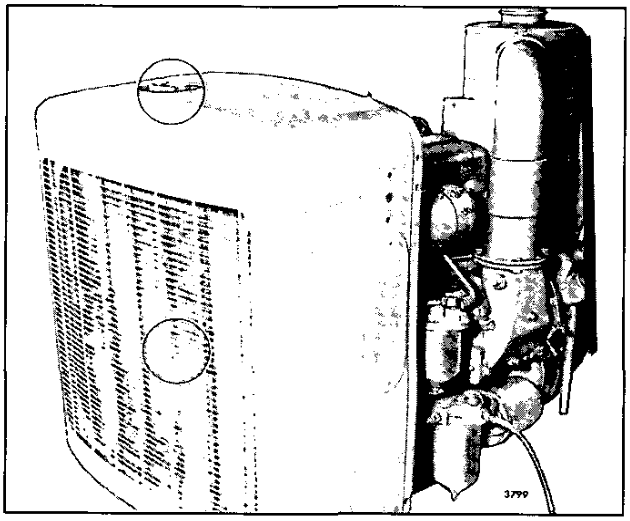
Item 19 – Emergency Shutdown

With the engine running at idle speed, check the operation of the emergency shutdown every 700 hours or 20,000 miles. Reset the air shutdown valve in the *open* position after the check has been made.

Item 20 – Engine (Steam Clean)

Steam clean the engine and engine compartment.

NOTICE: Do not apply steam or solvent directly to the battery–charging alternator, starting motor or electrical components as damage to electrical equipment may result.



Item 21

Item 21 – Radiator

Inspect the exterior of the radiator core every 12 months or 20,000 miles (700 hours) and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air.

CAUTION: To avoid personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Do not use fuel oil, kerosene or gasoline. It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 22 – Shutter Operation

Check the operation of the shutters and clean the linkage and controls.

Item 23 – Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 700 hours or 20,000 miles.

Item 24 – Governor

Check and record the engine idle speed and no–load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified.

A no–load speed higher than recommended will result in a full–load speed higher than rated and higher than the speed at which the engine was certified.

Overspeed Governor

Lubricate the overspeed governor, if it is equipped with a hinge–type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours or 15,000 miles. Avoid excessive lubrication and do not lubricate the governor while the engine is running.

Item 25 – Fuel Injectors and Valve Clearance

Check the injector timing and exhaust valve clearance as outlined in Section 14.2 and 14.1 every 50,000 miles. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 26 – Throttle Delay/Fuel Modulator

Inspect and adjust, if necessary, every 30 months or 50,000 miles.

The **Throttle Delay** system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay (Section 14.14).

Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the *full–fuel* position.

On the **Fuel Modulator**, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear and free operation. Also, inspect the operating surface of the lower roller, the roller pins at the cam pivot and the cam attachment to the piston. Replace parts, as required.

The fuel modulator must be set with the proper gage to achieve the correct fuel–to–air ratio (Section 14.14).

Item 27 – Battery–Charging Alternator

Battery–charging alternators are lubricated at time of manufacture and do not require further lubrication. Check terminals for corrosion and loose connections. Check for damaged or frayed insulation. Repair or replace wiring as required.

Item 28 – Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 2,000 hours or 60,000 miles. Tighten and repair as necessary.

Item 29 – Crankcase Pressure

Check and record the crankcase pressure every 2,000 hours or 60,000 miles (refer to Section 15.2).

Item 30 – Air Box Check Valves

Every 100,000 miles or approximately 3,000 hours remove the air box check valves, clean them in solvent and blow out the lines with compressed air. Inspect for leaks after servicing.

CAUTION: To avoid personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Item 31 – Fan Hub

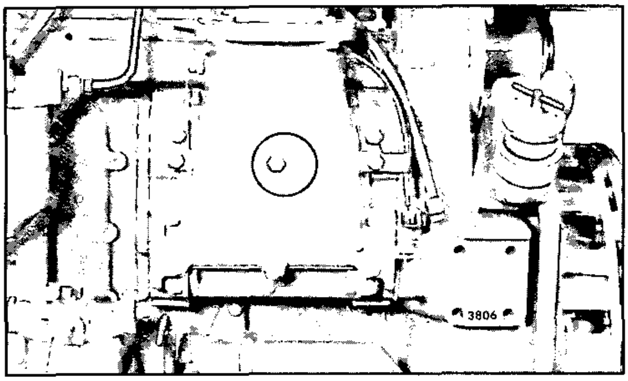
If the fan bearing hub assembly is provided with a grease fitting, use a hand grease gun and lubricate the bearings with one shot of Texaco Premium RB grease, or an equivalent Lithium base multi–purpose grease, every 20,000 miles (approximately 700 hours).

Every 2,500 hours or 75,000 miles (vehicle engines) or 4,000 hours (non–vehicle engines) clean, inspect and repack the fan bearing hub assembly with the above recommended grease (refer to Section 5.4).

At a major engine overhaul, remove and discard the bearings in the fan hub assembly. Pack the hub assembly, using new bearings, with Texaco Premium RB grease or an equivalent Lithium base multi–purpose grease.

Item 32 – Thermostats and Seals

Check the thermostats (see Section 5.2.1) and seals at 5,000 hours (non–highway engines), 200,000 miles (highway engines) or once a year (preferably at the time the cooling system is prepared for winter operation). The thermostats and seals should *always* be replaced at overhaul.



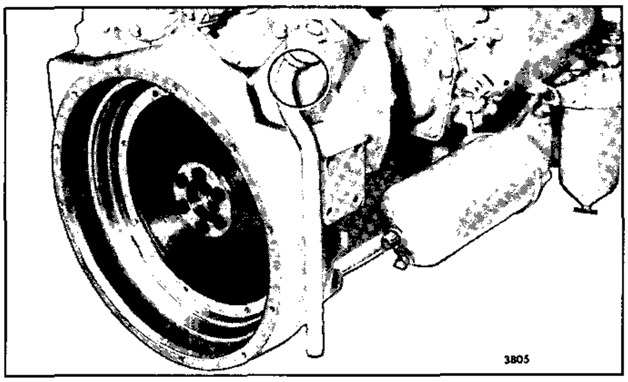
Item 33

Item 33 – Blower Screen

Inspect the blower screen and gasket assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) and, if necessary, clean the screen in fuel oil and dry it with compressed air.

CAUTION: To avoid personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Install the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.



Item 34

Item 34 – Crankcase Breather

Remove the externally mounted crankcase breather assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.

Item 35 – Fan (Thermo–Modulated)

DRIVE FLUID LEVEL – Check the fan drive fluid level to avoid improper operation and damage to the drive components.

Current modulated fan drive housings have an inspection plug for checking the fluid level. Formerly partial disassembly of the drive was necessary to make the fluid level check. Former units can be updated by installing a current drive housing which includes the fluid inspection plug and a grease fitting for lubricating the bearing.

1. Check the fan drive fluid level after the unit has been idle for at least 1/2 hour.
2. Turn the fan drive so that the inspection plug is 3/4″ below the horizontal center line, then allow the silicone fluid to drain down an additional five (5) minutes.
3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.
4. If the fluid does not flow from the hole, proceed as follows:
   a. Rotate the fan drive downward and observe when the fluid begins to flow from the hole. If it is necessary to lower the drain hole more than 2″ below the horizontal center line, the fan drive should be removed from the engine, disassembled and inspected for possible damage to the components.
   b. Turn the fan drive back so the inspection hole is 3/4″ below the horizontal center line and add fluid until the overflow point is reached. Replace the inspection plug.

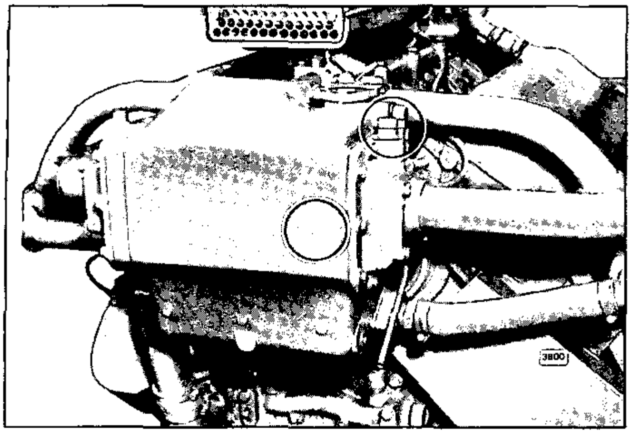
   Use only the manufacturer's Special 20 Cenistroke fluid.

DRIVE BEARING LUBRICATION – The fan drive bearing should be lubricated with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent).

The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Lubrication of the bearing in former assemblies requires the removal of the fan assembly and partial disassembly. The former assemblies can be updated to include a grease fitting by installing the current housing.

Item 36 – Engine Tune–Up

There is no scheduled interval for performing an engine tune–up. As long as the engine performance is satisfactory, no tune–up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

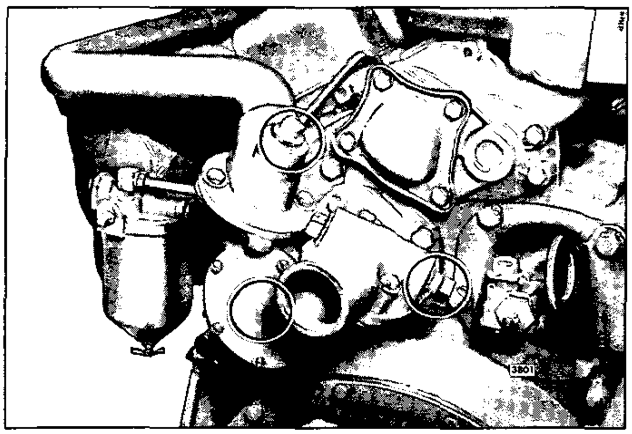


Item 37

Item 37 – Heat Exchanger Electrodes and Core

Heat exchanger electrodes ("zincs") should be removed and checked initially every 60 days, then as required or annually. Electrodes are generally found in the heat exchanger assembly, the raw water pump elbows, and the engine/marine gear auxiliary coolers. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours and inspect the heat exchanger core. If a considerable amount of scale or deposits are present, contact a *Detroit Diesel Service Outlet*.



Item 38

Item 38 – Raw Water Pump

Check the prime on the raw water pump daily. The engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.

- A raw water pump seal malfunction is indicated by leakage of water from the openings in the pump housing. These openings, located between the pump mounting flange and the inlet and outlet ports, must remain open at all times. Leaky seals require replacement. The raw water pump body or liner should also be checked for cracks or wear and replaced.

Item 39 – Power Generator

Follow the power generator manufacturer's lubrication and preventive maintenance recommendations at his suggested intervals.

Item 40 – Power Takeoff

Follow the power take–off manufacturer's lubrication and preventive maintenance recommendations at his suggested intervals.

Item 41 – Marine Gear

- Check marine gear oil level daily. Replace Allison marine gear lube oil and filter every 150 hours or every two years, whichever comes first. Replace DDC (Twin Disc) marine gear lube oil every 1,000 hours or every six months, whichever comes first.

• Item 42 – Torqmatic Converter

Follow the Torqmatic converter manufacturer's lubrication and preventive maintenance recommendations at his suggested intervals.

Item 43 – Hydrostarter System

If engine is equipped with a hydrostarter system, refer to Section 12.6.1 for lubrication and preventive maintenance.

• Item 44 – Blower Bypass Valve

Every 100,000 miles or approximately 3,000 hours, remove the bypass blower valve and clean it in solvent, if necessary. Inspect for free operation of the valve and any scoring of the piston, piston guide or sleeve assembly. Repair or replace, as required.

TROUBLESHOOTING

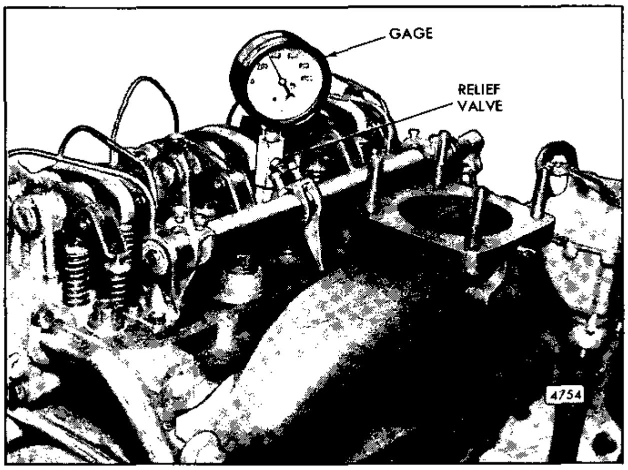


Fig. 1 – Checking Compression Pressure

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given below.

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.
2. Stop the engine and remove the valve rocker cover(s).
3. Check the valve clearance (refer to Section 14.1).
4. Start the engine. Then hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short–circuiting a spark plug in a gasoline engine.
5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.
6. If the cylinder is misfiring, check the following:
   a. Check the injector timing (refer to Section 14.2).
   b. Check the compression pressure.
   c. Install a new injector.
   d. If the cylinder still misfires, remove the cam follower (refer to Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushing.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one–half rated load until normal operating temperature is reached.
2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.
3. Remove the injector and install adaptor J 7915–02 and pressure gage and hose assembly J 6692 (Fig. 1).
4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.
5. Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*

Minimum Compression Pressure at 600 rpm				Altitude Above Sea Level	
Std. Engine		"N" Engine			
psi	kPa	psi	kPa	Feet	Meters
430	2 963	540	3 721	500	152
400	2 756	500	3 445	2,500	762
370	2 549	465	3 204	5,000	1 524
340	2 343	430	2 963	7,500	2 286
315	2 170	395	2 722	10,000	3 048

TABLE 1

Cylinder	Gage Reading	
	psi	kPa
1	525	3 617
2	520	3 583
3	485	3 342
4	515	3 548

TABLE 2

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In additon, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

   If the compression pressure readings were as shown in Table 2, it would be evident that No. 3 cylinder should be examined and the cause of the low compression pressure be determined and corrected.

   The pressures in Table 2 are for an "N" engine operating at an altitude near sea level. Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 3 *cylinder compression pressure indicates that* something unusual has occurred and that a localized pressure leak has developed.

   Low compression pressure may result from any one of several causes:

   A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool. A broken or stuck ring will not have a "spring-like" action.

   B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

Engine Out of Fuel

The problem in restarting an engine after it has run out *of fuel stems from the fact that after the fuel is exhausted* from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (38 litres) of fuel.
2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.
3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.
4. Start the engine. Check the filter and strainer for leaks.

   NOTICE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and *install the filler plug.*

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in Section 2.0 under *TroubleShooting.*

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow–by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the *Engine Operating Conditions* in Section 13.2. *The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.*

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an

exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold (except on turbocharged engines) by removing the 1/8" pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet (Fig. 1, Section 13.2). The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no–load) with the *Engine Operating Conditions* in Section 13.2.

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located two inches (2") above the air inlet housing (non–turbocharged engines) or the compressor inlet (turbocharged engines). When the insertion of a fitting at this point is not practical (non–turbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no–load) and compare the results with the *Engine Operating Conditions* in Section 13.2.

PROPER USE OF MANOMETER

The U–tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

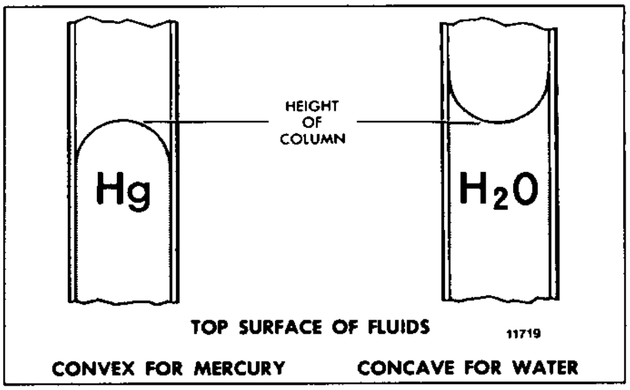
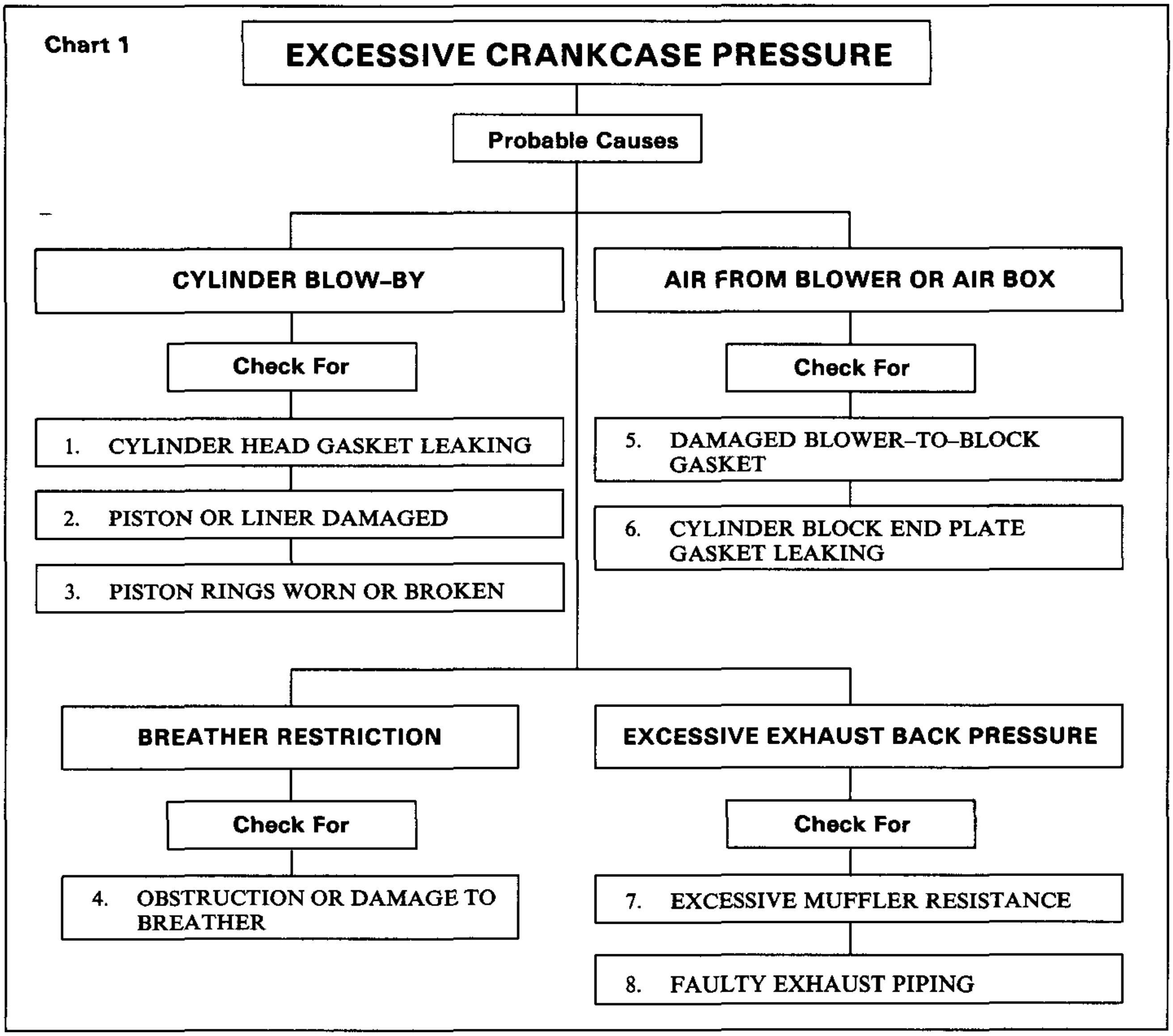


Fig. 2 – Comparison of Column Height for Mercury and Water Manometers

PRESSURE CONVERSION CHART

1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	13.6000" water
1" mercury	=	.4910 psi
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury
1 psi	=	6.895 kPa
1 kPa	=	.145 psi

TABLE 3



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
2. Inspect the piston and liner and replace damaged parts.
3. Install new piston rings.
4. Clean and repair or replace the breather assembly.
5. Replace the blower–to–block gasket.
6. Replace the end plate gasket.
7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 2

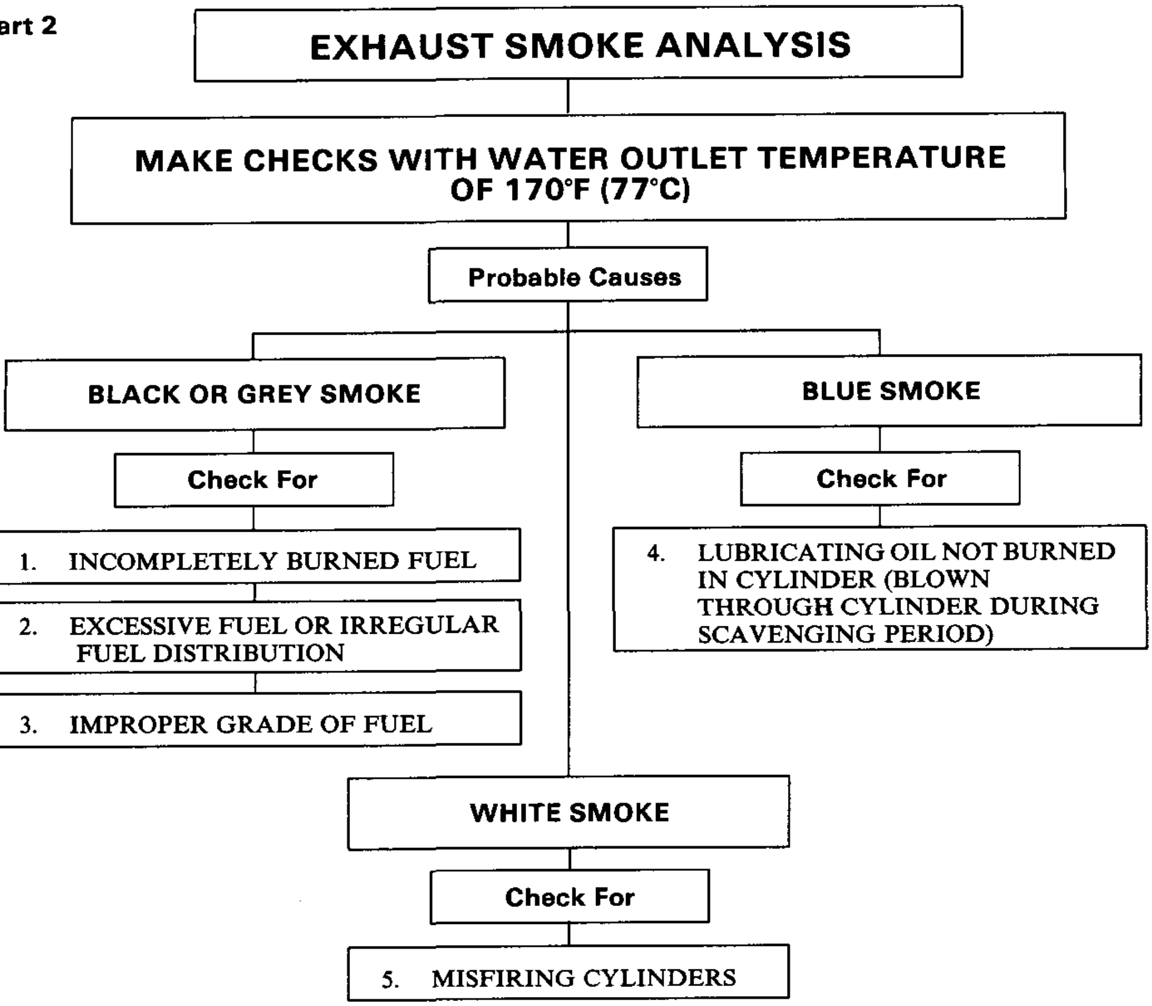

EXHAUST SMOKE ANALYSIS
MAKE CHECKS WITH WATER OUTLET TEMPERATURE OF 170°F (77°C)
Probable Causes
BLACK OR GREY SMOKE
Check For
1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL
BLUE SMOKE
Check For
4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)
WHITE SMOKE
Check For
5. MISFIRING CYLINDERS

Chart 2

EXHAUST SMOKE ANALYSIS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

   High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

   Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it, if necessary.

2. If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

   If the engine is equipped with a fuel modulator, check the cam to determine if it is stuck in the full fuel position. Verify tightness of the roller lever clamp on the control tube. Determine correctness (refer to Section 14.14) of the installed fuel modulator piston spring and check if the spring has taken a permanent "set" or if the spring rate is too low.

   The above affects only excessive acceleration smoke, but does not affect smoke at constant speed.

   Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune–up.

   Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune–up.

   Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to *Fuel Specifications* in Section 13.3.

4. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* Chart.

5. Check for faulty injectors (see *Locating a Misfiring Cylinder* in the front of this section) and replace, as necessary.

   - White smoke or misfire at idle may occur when any one or more injector's idle output is considerably higher or lower than the remaining injectors operated by the same control tube. Significant differences in injector idle output will affect firing impulses since some cylinders are receiving too much fuel while others are receiving little or no fuel at idle.
   - The cylinder that is not firing at idle may be detected by shorting out the injector with a screwdriver. Depress the injector follower to prevent injector operation. If there is a change noted in the engine (i.e., noise or RPM), the injector can be considered operational. If no change is noted in the engine, one cause could be that the injector is not providing sufficient fuel at idle for combustion. The rack screw should then be adjusted to increase fuel output. Turn the injector rack screw slightly (no more than 1/8 of a turn) to change the idle output. This adjustment should only be made after any heavy hitting injectors have been identified and adjusted to reduce idle output. Heavy hitting injectors generally contribute to a louder cylinder firing impulse/sound. After adjusting the suspected problem injectors, accelerate the engine several times and allow it to return to idle.

   Check for low compression and consult the *Hard Starting* Chart.

   The use of low cetane fuel will cause this condition. Refer to *Fuel Specifications* in Section 13.3.

Chart 3

HARD STARTING

Probable Causes

ENGINE WILL NOT ROTATE

Check For

1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE

LOW CRANKING SPEED

Check For

4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER

NO FUEL

Check For

7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL–FUEL POSITION

LOW COMPRESSION

Check For

9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING

INOPERATIVE STARTING AID AT LOW AMBIENT TEMP

Check For

14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 3

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubrication Specifications* in Section 13.3 for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

   Replace terminals that are damaged or corroded.

   At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* Chart.

8. Check for bind in the governor–to–injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the exhaust valves.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the exhaust valve clearance.

13. Remove the flywheel housing cover at the blower drive support. Then, remove the snap ring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (see Section 3.4 or 3.4.1).

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aids.*

Chart 4

ABNORMAL ENGINE OPERATION

Probable Causes

UNEVEN RUNNING OR FREQUENT STALLING

Check For

1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)

LACK OF POWER

Check For

6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION

DETONATION

Check For

13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 4

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and if the temperature does not reach normal operating temperature while the engine is operating, consult the *Abnormal Engine Coolant Temperature* Chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* Chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune–up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the *Hard Starting* Chart if compression pressures are low.

5. Erratic engine operation may be caused by governor–to–injector operating linkage bind or by faulty engine tune–up. Perform the appropriate engine tune–up procedure as outlined for the particular governor used.

6. If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

   If equipped with a fuel modulator, determine if there is any interference with the roller assembly or roller contact with the cam at *wide open throttle (WOT)* position. Check for burrs and binding on the piston and bracket bore. Determine correctness (refer to Section 14.14) of the installed fuel modulator spring and check if the spring has taken a permanent "set", or if the spring rate is too high.

   Perform an engine tune–up if performance is not satisfactory.

   Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel fuel or Insufficient Fuel Chart.*

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

   Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

   Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

   Check the compression pressures (consult the *Hard Starting* Chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

10. Refer to Item 13 of this Chart.

11. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10°F (6°C) temperature rise above 90°F (32°C) will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity of lubricating oil that is used in the engine.

    Clean the air box drain tubes and check valve (if used) to prevent accumulation that may be picked up by the air stream and enter the engine cylinders. Inspect the check valve as follows:

    A. Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.

    B. Run the engine and note the air flow through the valve at idle engine speed.

    C. If the check valve is operating properly, there will be no air flow at engine speeds above idle.

    Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

    Check for a defective blower–to–block gasket. Replace the gasket, if necessary.

14. Refer to Item 1 of this Chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune–up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Chart 5

NO FUEL OR INSUFFICIENT FUEL

Probable Causes

AIR LEAKS

Check For

1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY

FLOW OBSTRUCTION

Check For

5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURES LESS THAN 10°F. (6°C.) ABOVE POUR POINT OF FUEL

FAULTY FUEL PUMP

Check For

7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING

FAULTY INSTALLATION

Check For

10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 5

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.
2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.
3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element. element.
4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary,
6. Consult the *Fuel Specifications* for the recommended grade of fuel.
7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.
8. Replace the gear and shaft assembly or the pump body.
9. Check the condition of the fuel pump drive and blower drive and replace defective parts.
10. Replace with larger tank–to–engine fuel lines.
11. Install a restricted fitting in the return line.
12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve, if necessary. If the valve is inoperative, replace it with a new valve assembly.
13. Check the engine fuel spill–back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. AUTOMATIC OIL FILLER
4. OIL PULLOVER – AIR COMPRESSOR
5. OVERFILLED CRANKCASE
6. PLUGGED BREATHERS
7. HIGH CRANKCASE PRESSURE
8. BLUE EXHAUST SMOKE
9. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

10. BLOWER OIL SEALS LEAKING
11. TURBO OIL SEALS LEAKING
12. OIL COOLER CORE LEAKING
13. WORN EXHAUST VALVE GUIDES

OIL CONTROL AT CYLINDER

Check For

14. LOW COMPRESSION
15. PISTON PIN RETAINER LOOSE
16. OIL CONTROL RINGS WORN, BROKEN, IMPROPERLY INSTALLED OR SCORED
17. EXCESSIVE OIL IN AIR BOX
18. DIRT IN AIR INTAKE SYSTEM
19. SCORED LINERS OR PISTONS
20. EXCESSIVE INSTALLATION ANGLE
21. EXCESSIVE OIL IN CRANKCASE

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

SUGGESTED REMEDY

NOTICE: Lube oil consumption must be verified after each repair is made.

1 & 2. Repair oil leaks by replacing necessary gaskets, seals or tightening connections. Steam cleaning the engine and operating at no–load rpm, (engine at operating temperature) will often reveal excessive oil leaks.

3. Consult the original equipment manufacturer for proper repair of the automatic oil filler system.

4. Check the air compressor for oil pullover and/or remove and replace the compressor.

5. Check dipstick and tube for proper oil pan levels to correct over filled crankcase.

6. Check crankcase pressure. Clean breathers and recheck crankcase pressure.

7. Overhaul blower, turbocharger or rekit engine (refer to Items 10, 11, 15 and 16). Also, refer to the *Excessive Crankcase Pressure* chart.

8. Remove and inspect exhaust manifolds and stacks for wetness or oil discharge. Excessive clearance between the valve stem and the valve guide can produce oil in the cylinders and stack. Repair the valve guides and/or install valve stem seals.

9. Refer to the *Abnormal Engine Operation* chart.

10. Remove the piping from the air inlet housing and remove from the blower. Operate the engine at approximately one–half throttle and at idle and inspect blower end plates for evidence of oil leakage past the seals. Use a flashlight to illuminate the end plates. If excessive oil leakage is evident on the end plates, overhaul blower.

    CAUTION: The blower rotors are exposed and rotating during this test. Contact with the rotors must be avoided as personal injury could result.

11. Check for indications of oil on compressor or turbine sides of the turbocharger. Refer to Section 3.5 of the Service Manual for the proper procedure to determine turbocharger oil seal leakage.

12. Pressure test cooling system. If leak is found, remove and replace the oil cooler.

Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then, use a good grade of cooling system cleaner to remove the oil from the cooling system.

13. Replace worn exhaust valve guides.

14. Take compression test – refer to Item 16.

15. Run engine at idle speed with the air box cover removed (one at a time) to determine if oil is uncontrolled as evidenced by slobbering out the liner ports. Inspect all cylinders as more than one may be slobbering. Repair affected cylinders. Slobbering can also be caused by worn oil control rings.

    CAUTION: Hot lubricating oil could be blown out the air box during this test. Contact with the hot oil could cause severe burns.

16. Check for faulty engine air induction system allowing contaminated air to enter the engine. A compression test with excessively low readings will indicate worn out cylinders. Remove and replace cylinder kits.

17. Refer to Items 10, 11, 15 and 16.

18. Refer to Item 16.

19. Check the crankshaft thrust washers for wear. Replace wore and defective parts.

20. Decrease the installation angle.

21. Fill the crankcase to the proper level only.

Chart 7

LOW OIL PRESSURE

MAKE CHECKS WITH WATER OUTLET TEMPERATURE OF 170°F (77°C)

Probable Causes

LUBRICATING OIL

Check For

1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY

POOR CIRCULATION

Check For

3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING

PRESSURE GAGE

Check For

8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY

OIL PUMP

Check For

12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. LOOSE END COVER BOLTS
17. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the *Lubrication Specifications* in Section 13.3 for the recommended grade and viscosity of oil.

   Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to Section 2.0.

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gage and replace the gage if found faulty.

9. Remove and clean the gage line; replace it, if necessary.

10. Remove and clean the gage orifice.

11. Repair or replace defective electrical equipment.

12. Remove and clean the oil pan and oil intake screen. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the oil pan and tighten the oil pump end cover bolts.

17. Remove the flange and replace the gasket.

Chart 8

ABNORMAL ENGINE COOLANT OPERATING TEMPERATURE

Probable Causes

ABOVE NORMAL

Check For

1. INSUFFICIENT HEAT TRANSFER
2. POOR CIRCULATION

BELOW NORMAL

Check For

3. IMPROPER CIRCULATION
4. EXCESSIVE LEAKAGE AT THERMOSTAT SEAL

SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

   Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

   Adjust fan belts to the proper tension to prevent slippage.

   Check for an improper size radiator or inadequate shrouding.

   Repair or replace inoperative temperature–controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

   Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

   Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

   Check the water pump for a loose or damaged impeller.

   Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

   Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

   Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

   Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

VEHICLE LOW POWER / PERFORMANCE AT LOW MILEAGE

1. **Determine the basis for the concern.** Does the concern indicate slow acceleration from a stop or slow engine recovery when changing gears? The answers to these questions often provide the proper information for the investigation.

   A. Is the truck being driven according to recommended procedures? For example, down shifting an engine with a throttle delay at high speed (rather than at low speed) will cause the engine to recover power slowly, creating an impression of low power. Driver training would help.

   B. Are the driver's expectations of vehicle performance realistic, considering truck gear ratios, loads and engine rated speed and power? The distributor or regional office should be consulted to assist in evaluation of vehicle performance (shift points and gradability, for example).

2. **Check customer engine and vehicle order specifications and vehicle road speeds, if necessary.**

   A. Determine if the engine no–load speed (rpm) and horserpower meet customer order specifications. The O.E.M. truck dealer or Detroit Diesel Corporation Regional Office can assist in this area.

   B. It is normal for the actual engine no–load speed to be slightly less (5 to 20 rpm) than the no–load speed set at Detroit Diesel Corporation due to engine accessories (air compressor, power steering pump, etc.) installed by the O.E.M. There is a $\pm$ 25 rpm manufacturing tolerance for no–load speed setting. It would be normal, therefore, for an engine order specification of 2050 rpm no–load speed to check out at 2025 to 2075 rpm in the vehicle.

   C. The rated full–load engine speed will not change because of a slight change of no–load speed (rpm) resulting from the addition of O.E.M. accessory loads.

   D. Engine speed combined with rear axle ratios and tire size provide the resultant vehicle geared road speed which may be a basis for customer concern.

   E. Vehicle highway speed is a result of the gear ratios, engine speed and gross vehicle weight. For purposes of discussion, geared speed is the speed the truck would reach with the transmission in direct drive and the engine at rated speed. Geared speed (GS) in Miles Per Hour (mph) can be computed as follows:

$$GS = \frac{\text{Full Load engine RPM} \times 60}{\text{Axle ratio} \times \text{tire revolutions/mile}}$$

EXAMPLE:

$$GS = \frac{1900 \text{ rpm} \times 60}{4.11 \times 504} = 55 \text{ mph}$$

The vehicle could be expected to have a maximum road speed somewhat more than 55 mph (2050 x 55/1900 – 59.3) mph on level pavement with 2050 rpm no–load engine speed. This maximum vehicle speed of 59.3 mph may not be reached because of parasitic and frictional power losses. These power losses are a result of the vehicle power train and engine–driven accessories. At speeds over 50 mph wind resistance can be responsible for the greatest engine power or road speed loss.

These vehicle speed calculations can be used to compare designed performance with actual performance. In the example it would be expected that the vehicle should operate between approximately 55 and 59 mph with typical loads and on level pavement. If during tests the loaded vehicle operates at calculated road speeds on level pavement (without a head wind), re–evaluate the source and reason for the power concern. Average the speeds attained on a two or three mile level run both into the wind and with the wind, to determine maximum possible road speed with vehicle unloaded.

   F. Accuracy of the vehicle speedometer and tachometer is important. Low–reading instruments have caused some low power concerns. These instruments should be checked for accuracy at both high and low speed.

3. **Check for improper assembly of engine related parts and accessories installed by the vehicle manufacturer (O.E.M.).** Parts and accessories that can contribute to low power/performance are:

   A. Throttle linkage and governor shut down (adjustment).

   B. Fuel supply and return line (size and installation).

   C. Fuel filters (leaking or contaminated).

D. Fuel tanks (construction, return and supply line installation: fuel temperature should not exceed maximum allowable) – (see Section 2.5.1)

E. Air intake and exhaust components (size and installation).

F. Jacobs brake (installation and adjustment). See Items 11 thru 14.

G. Fuel heater (restriction).

H. Water separator (restriction).

4. **Check governor throttle and shutdown linkage adjustment as follows:**

A. Improper adjustment of vehicle throttle linkage and governor shut down are the most frequent causes of low power/performance concerns. When the vehicle throttle (accelerator pedal) is fully depressed, the governor throttle lever should move from idle to the full–throttle position. Low power will result if the vehicle throttle linkage cannot reach the full–throttle position.

B. The governor run–stop lever (mechanism) normally installed by the O.E.M. must be adjusted to allow an air gap or clearance (.020 min.) between the stop lever and the air or electric solenoid. Improper adjustment (lack of air gap) of the run–stop lever mechanism will not allow the injector control rack(s) to reach the full–fuel position, thus resulting in low power/performance.

5. **Check fuel system for pressure and flow as follows:**

A. First, start and run the engine. Check for proper fuel pressure at specified engine speeds (refer to Section 13.2). Checking fuel pressure will reveal conditions related to fuel flow restriction, fuel pump relief valve operation and performance conditions caused by high or low fuel pressure.

B. If fuel pressures are according to specifications, disconnect the fuel return line from the fitting at the fuel tank and check return flow rate. Hold open end in a clean container. Start and run the engine at 1000 rpm. Place the end of the fuel return line beneath the fuel level in the receptacle. After a few minutes no air or gas bubbles should be present. If any bubbles are detected, determine the cause for air entering the fuel system and repair, as required. Air in the fuel system is normally caused by a leak at fuel connections and/or filters between the suction side of the fuel pump to the supply tank and not between the pressure side of the pump and engine. Minimum fuel return rates are provided in Section 2.0.

C. If no air bubbles are present and return rate is below minimum specifications, check for fuel flow restrictions which can be caused by fuel heaters, water separators, undersize, improperly routed or damaged fuel lines,contaminated fuel filters or high fuel presure resulting from a plugged restricted fitting.

D. Always make sure there is sufficient fuel supply (at least 1/3 of normal capacity) in the fuel tanks.

6. **Check crankcase for lube oil overfill.** Overfilled engine crankcase can cause low power and higher–than–normal lubricating oil temperature. Normally, oil levels should be at or slightly below the oil pan–to–block split line with vehicle on level ground.

7. **Check engine horsepower, if necessary.** First, insure engine is at the proper operating temperature. The horsepower measurement before and after corrective action can be used to evaluate the results of the troubleshooting and repair effort. Record this power at appropriate time while troubleshooting. The actual horsepower reading should not be used to judge if engine performance is satisfactory but used only to see if a noticeable power change has taken place. Fuel quality, engine–driven accessories, drive line or tires can contribute to low power readings. It should be noted that No. 1 diesel fuel can produce up to 7% less horsepower than No. 2 fuel. Blends of No. 1 and No. 2 (common in winter) will produce less horsepower, depending on the percent of the blend.

8. **Check for evidence of brake dragging, bad driveline bearings or misaligned axles.**

9. **Check for excessive air intake restriction.** Undersize or dirty air cleaner elements, damaged or obstructed air inlet piping can also cause low power.

10. **Check turbocharger exhaust connections and exhaust system components.** A damaged, undersized or otherwise restricted muffler or exhaust back pressure and subsequent loss of engine power.

11. **Check for proper location of rocker cover(s).** If the cover(s) has been pushed towards the injector control tube assembly (inboard on V engines), the injector control lever movement may be restricted by the cover. This condition will not allow injectors to reach full fuel, thereby causing a low power/performance condition. Situations that can cause this conditon are:

A. Use of engine lifting apparatus that contacts the rocker cover(s).

B. Incorrect reinstallation of rocker cover(s) after removal for various reasons (Jacobs brake installation, for example).

12. **Check throttle delay or fuel modulator operation.** If the engine is equipped with a throttle delay, check for the proper setting and a plugged discharge orifice. If the engine is equipped with a fuel modulator, check for a pinched air supply line. Determine if there is any interference with the roller assembly or improper roller–to–cam contact when governor throttle lever is in the full–throttle position. Check for smooth operation of the piston in the bore. Check for excessive air leakage between the piston and cylinder which may be caused by excessive piston clearance due to wear.

13. **Check governor–to–injector linkage.** Removal of the governor and rocker cover(s) will be necessary to detect any binding or restriction of linkage movement.

14. **Check engine tune–up and make necessary corrections.** If all previous steps do not reveal cause for a confirmed low power/performance condition, engine tune–up settings may be considered a probable cause. It is normal for tune–up settings to vary when using correct setting procedures. Some items influencing tune–up measurements are differences in gages, individuals and mechanical variations.

At Detroit Diesel Corporation, engine tune–up settings are conducted using electronic and dial indicator gaging equipment. Finally, to determine that tune–up is within accepted tolerances, the engine is tested to assure that horsepower output is to published specifications.

Jacobs brake installation or adjustment errors can cause low power/performance conditions.

When making tune–up adjustments, refer to Section 14.0 for specifications.

Periodic inspection of tune–up gages is necessary to determine if damaged or worn. Injector timing gages are marked with the timing dimensions and have an allowable tolerance of ± .001 . Rack gages are marked with the specific dimension and have an allowable tolerance of ± .002 .

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

   Do not drain the fuel system or the crankcase after this run.
4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1.
5. Fill the cooling system with a properly inhibited ethylene glycol base antifreeze solution (refer to Coolant Specifications in Section 13.3). Drain the raw water system and leave the drain cocks open.
6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.
7. Seal all of the engine openings. The material used for this purpose must be waterproof, vapor proof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission and priming the raw water pump, if used.

EXTENDED STORAGE (more than 30 days)

To prepare an engine for extended storage, (more than 30 days), follow this procedure:

1. Drain the cooling system and flush with clean, soft water.

   Refill with a properly inhibited ethylene glycol base antifreeze solution (refer to coolant Specifications in Section 13.3).
2. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.
3. Reinstall the injectors, time them and adjust the exhaust valve clearance.
4. Circulate the coolant by operating the engine until normal operating temperature is reached (see Section 13.2).
5. Stop the engine.
6. Drain the engine crankcase, then reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.
7. Fill the crankcase to the proper level with a 30 weight preservative lubricating oil MIL–L–21260C, Grade 2.
8. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it isn't convenient to drain the fuel tank (i.e., marine) use a separate portable supply of the recommended fuel.

NOTICE: If engines in vehicles or marine units are stored where condensation of water in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint to 125 gallons of fuel, or .010% by volume. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF, or equivalent, to the fuel. When using a biocide, follow the manufacturer's concentration recommendations, and observe all cautions and warnings.

9. Drain and disassemble the fuel filter and strainer. Discard the used elements and gaskets. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene, and reinstall on the engine. If spin–on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene, and reinstall on the engine.

10. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine.

11. Refer to Section 3.1 and service the air cleaner.

12. MARINE GEAR

    A. Drain the oil completely and refill with clean oil of the recommended grade and viscosity. Remove and clean or replace the strainer and filter element.

    B. Start and run the engine at 600 rpm for ten minutes to coat all of the internal parts of the marine gear with clean oil. Engage the clutches alternately to circulate clean oil through all of the moving parts.

NOTICE: The performance of this step is not necessary on torque converter units.

13. TORQMATIC CONVERTER

    A. Start and operate the engine until the temperature of the converter oil reaches 150°F (66°C).

    B. Stop the engine, remove the converter drain plug and drain the converter.

    C. Remove the filter element.

    D. Start the engine and stall the converter for **twenty seconds** at 1000 rpm to scavenge the oil from the converter. *Due to lack of lubrication, do not exceed the 20 second limit.*

    E. Install the drain plug and a new filter element.

    F. Fill the converter to the proper operating level with a commercial preservative oil which meets Government specifications MIL–L–21260C, Grade 2. Oil of this type is available from the major oil companies.

    G. Start the engine and operate the converter for at least ten minutes at a minimum of 1000 rpm. Engage the clutch, then stall the converter to raise the oil temperature to 225°F (107°C).

NOTICE: Do not allow the oil temperature to exceed 225°F (107°C). If the unit does not have a temperature gage, *do not stall the converter for more than thirty seconds.*

    H. Stop the engine and allow the converter to cool to a temperature suitable to the touch.

    I. Seal the breather and all of the exposed openings with moisture–proof tape.

    J. Coat all exposed, unpainted surfaces with preservative grease. Position all of the controls for minimum exposure and coat them with grease. The external shafts, flanges and seals should also be coated with grease.

14. POWER TAKE–OFF

    A. Use an all purpose grease such as Shell Alvania No. 2, or equivalent, and lubricate the clutch throwout bearing, clutch pilot bearing, drive shaft main bearing, clutch release shaft and the outboard bearings (if so equipped).

    B. Remove the inspection hole cover on the clutch housing and lubricate the clutch release lever and link pins with a hand oiler. Avoid getting oil on the clutch facing.

    C. If the unit is equipped with a reduction gear, drain the gear box and flush with light engine oil. If the unit is equipped with a filter, clean the shell and replace the filter element. Refill the gear box to the proper level with the grade of oil indicated on the name plate.

15. TURBOCHARGER

Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

16. HYDROSTARTER SYSTEM

Refer to Section 12.6.1 for the lubrication and preventive maintenance procedure.

17. Apply a *non-friction* rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

    NOTICE: Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

18. Drain the engine cooling system.

19. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.

20. Remove and clean the battery and battery cables with a baking soda–water solution and rinse with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32°F or 0°C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

21. Insert heavy paper strips between the pulleys and belts to prevent sticking.

22. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

23. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

24. Protect the engine with a good weather–resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

Detroit Diesel Corporation does not recommend the outdoor storage of engines (or transmissions). Nevertheless, DDC recognizes that in some cases outdoor storage may be unavoidable. If units must be kept out–off–doors, follow the preparation and storage instructions already given. Protect units with quality, weather–resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

> **NOTICE:** *Do not use plastic sheeting for outdoor storage.* Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crankcase. Reinstall the drain plug. Then refer to *Lubrication System* in Section 13.1 and fill the crankcase to the proper level, using a pressure prelubricator, with the recommended grade of lubricating oil.

6. Fill the fuel tank with the fuel specified under *Fuel Specifications* (Section 13.3).

7. Close all of the drain cocks and fill the engine cooling system with a properly inhibited ethylene glycol base antifreeze solution (refer to Section 13.3).

8. Install and connect the battery.

9. Service the air cleaner as outlined in Section 3.1.

10. POWER GENERATOR

    Prepare the generator for starting as outlined under *Operating Instructions* in Section 13.

11. MARINE GEAR

    Check the marine gear; refill it to the proper level, as necessary, with the correct grade of lubricating oil.

12. TORQMATIC CONVERTER

    A. Remove the tape from the breather and all of the openings.

    B. Remove all of the preservative grease with a suitable solvent.

C. Start the engine and operate the unit until the temperature reaches 150°F (66°C). Drain the preservative oil and remove the filter. Start the engine and stall the converter for twenty seconds at 1000 rpm to scavenge the oil from the converter.

NOTICE: A Torqmatic converter containing preservative oil should only be operated enough to bring the oil temperature up to 150°F (66°C).

D. Install the drain plug and a new filter element.

E. Refill the converter with the oil that is recommended under *Lubrication and Preventive Maintenance* (Section 15.1).

13. POWER TAKE–OFF

Remove the inspection hole cover and inspect the clutch release lever and link pins and the bearing ends of the clutch release shaft. Apply engine oil sparingly, if necessary, to these areas.

14. HYDROSTARTER

A. Open the relief valve on the side of the hand pump and release the pressure in the system.

B. Refer to the filling and purging procedures outlined in *Hydraulic Starting System* (Section 12.6.1). Then drain, refill and purge the hydrostarter system.

15. TURBOCHARGER

Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time* in Section 13.1.

16. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause a smoky exhaust for a few minutes.

NOTICE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune–up.

ALPHABETICAL INDEX

*General Information and Cautions Section

*General Information and Cautions Section

*General Information and Cautions Section

 May, 1990

*General Information and Cautions Section

